A Lossy, Dictionary-based Method for Short Message Service (SMS) Text Compression

Mini-dissertation , M.Sc. Information Technology

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This paper is accompanied by a DVD with source code, build scripts, binaries and the LD-based dictionary in text format. See readme.txt for details.

I know the meaning of plagiarism and declare that all of the work in the document, save for that which is properly acknowledged, is my own.

Abstract

Short message service (SMS) message compression allows either more content to be fitted into a single message or fewer individual messages to be sent as part of a concatenated (or long) message. While essentially only dealing with plain text, many of the more popular compression methods do not bring about a massive reduction in size for short messages. The Global System for Mobile communications (GSM) specification suggests that untrained Huffman encoding is the only required compression scheme for SMS messaging, yet support for SMS compression is still not widely available on current handsets. This research shows that Huffman encoding might actually increase the size of very short messages and only modestly reduce the size of longer messages. While Huffman encoding yields better results for larger text sizes, handset users do not usually write very large messages consisting of thousands of characters. Instead, an alternative compression method called lossy dictionary-based (LD-based) compression is proposed here. In terms of this method, the coder uses a dictionary tuned to the most frequently used English words and economically encodes white space. The encoding is lossy in that the original case is not preserved; instead, the resulting output is all lower case, a loss that might be acceptable to most users. The LD-based method has been shown to outperform Huffman encoding for the text sizes typically used when writing SMS messages, reducing the size of even very short messages and even, for instance, cutting a long message down from five to two parts.

Keywords: SMS, text compression, lossy compression, dictionary compression

Preface

This mini-dissertation concludes my studies towards the Masters in Information Technology at the University of Cape Town. The topic of SMS compression was not the original one I investigated. At first, I wrote code to send binary attachments such as PDF and MP3 files by SMS. The experiment worked, but then I had to admit how impractical such a pursuit would be; it takes a very large number of SMS messages to transfer even a tiny PDF document. I then started thinking whether to compress the attachments prior to transmission. When compressing the attachments failed to sufficiently reduce the size to make sending SMS attachments viable, I abandoned the idea completely. It was then that I started wondering about the merits of compressing plain-text SMS messages. The idea seemed worth exploring, but I still had to convince the department to let me undertake the research as part of my Masters project. Professor Gary Marsden from the department is actively involved in the field of mobile interaction. I decided to pitch my idea in the hope I might convince him to take on the role of supervisor. Professor Marsden was immediately supportive of the idea and I want to thank him for allowing me the freedom to pursue a topic of my own interest. I also want to thank my girlfriend, Allison Johnson, for the the support she gave me throughout the time I was working on the dissertation. Thank you also for proofreading my writing!

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Chapter 1 - Introduction

1.1 Motivation

Mobile SMS is an incredibly successful technology. In December 2008, there were 4 billion mobile phone subscribers [1], and a 2007 report forecasts that, by 2012, the number of SMS messages sent will total 3.7 trillion globally [2]. In addition, in 2008, more than 29 billion messages were sent in Germany alone. This is 15% more than in 2007, and the number expected in 2009 is even greater owing to the popularity of technologies such as Twitter [3]. In the UK messages totalled 41.8 billion, 56.9 billion and 78.9 billion in 2006, 2007 and 2008 respectively [4]. These figures also amount to huge profits and, in 2006 and 2008, the SMS industry globally was worth $81 and $151 billion respectively. In 2013 that figure is expected to rise to $212 billion globally [5].

The market appeal of SMS messaging is proportional to the simplicity of the technology, and it is in developing countries that SMS messaging is seeing its largest growth. Despite its success, the technology has an inconvenient limitation, namely, a 160-character-per-SMS message limit. Initially, users would type their message up to the number of allowed characters and, if the message was not yet finished, send another one. Handsets eventually automated this process, allowing users to type a long message in its entirety and send the message. Without prompting the user, the handset breaks the message into parts, labels the sequence of each part, and then transmits the parts in sequence. As the parts are received, the receiving handset processes the sequence numbers and integrates the message parts in the correct order for the recipient to view as a whole. This feature is called concatenated (or long) SMS, and while it offers usability convenience, it actually further restricts the numbers of characters that can be typed per SMS message. That is, concatenated SMS requires a special header to be sent with every message, leaving only 153 characters for the user. Users are also billed the price of a normal SMS message for every part comprising the whole. A 307-character SMS message is thus billed as three messages (153 + 153 + 1), whereas only two messages would be billed in the absence of automatic concatenation (160 + 147).

The profit margin of SMS messages is near 90%, and so the consumer is the big loser here. This forces us to consider why concatenated messages are not billed as single messages, as the way in which SMS messages are charged makes them one of the most expensive forms of data transfer in existence. In the UK, it costs 374.49 GBP to transmit just 1 MB of data via SMS at 2008 rates. This makes it 42 times more expensive than downloading the same amount of data from the Hubble space telescope for which NASA charges 8.85 GBP per megabyte [6].

1.2 Problem statement

The goal of this study is to design, implement and evaluate a dictionary-based method for compressing English SMS text messages. We would have achieved our objective if, by applying the developed compression scheme, an SMS can be transmitted and received in fewer parts than which would be required without any form of compression – the standard case for SMS transmission.

It is easy for a design to fall short in practice and to avoid this mistake, an actual, working prototype is built and tested against. Additionally, we will look at whether the method designed is a better fit for SMS compression than other known compression methods such as Huffman encoding. The basis for comparison is simple – whichever method requires the fewest parts to transmit a specific message is the more suitable candidate for SMS compression. Among the compression methods, special attention is given to Huffman encoding as it is the only method officially prescribed by the GSM specification – albeit compression in general is not supported, as far as this author could determine, on any of the leading handsets.

1.3 Dissertation outline

Chapter 2 provides background information on those aspects of SMS technology and compression relevant to this study. Chapter 3 discusses related work from literature. Chapter 4 covers the design and implementation of the compression method, the scientific approach taken to evaluate the outcome and the metrics involved. Chapter 5 presents and discusses the findings and results. Chapter 6 presents the conclusion, and Chapter 7 suggests areas and ideas for future work.

Chapter 2 - Background

2.1 SMS

Short message service (SMS) is a communication protocol for transmitting text messages over the GSM network. The technology was introduced by the European Telecommunication Standards Institute in 1991 [7]. SMS works quite simply: when a message is punched into a handset, it is sent to a short message service centre. It is the job of the SMS centre to deliver the message to the recipient or store the message for a later retry if the recipient cannot be reached, for example, when a phone is switched off. There is no guarantee that an SMS message will be delivered, but operators usually make their best attempt and only discard the message after a few days if they have no success.

The official terminology for a device that sends or receives an SMS message is a short message service entity (SMSE); this term is used to describe, for example, a personal computer, mobile phone, GSM modem or any other device that can send and/or receive SMS messages directly over the GSM network. Although SMS is a standard, required part of the GSM network, more recently the technology has been carried over to developed wireless networks, such as 3G. Messages are limited to 160 characters, however, as a remnant of the GSM implementation in which messages were transmitted using the Mobile Application Part of the SS7 signalling protocol [8], which limits payloads to 140 octets (8-bit bytes) or 1120 bits. In order to represent text characters as binary digits, a mapping set is required. This is the same method used by personal computers for storing text. Every character in the language is represented by a unique binary codeword. US-ASCII is a widely used binary alphabet (or character set) in which every Latin character is assigned a unique 7-bit pattern. US-ASCII caters mainly for English, so in order to support symbols from other languages, a much larger character set is required. There are many different implementations, but Unicode UTF-8 and UTF-16 are some of the more popular ones. The implementers of the GSM alphabet have had to deal with the same issues; it comes as no surprise then that the default alphabet for English and western European languages, called ETSI GSM 03.38, closely resembles US-ASCII and also uses 7-bit codewords [9]. Messages written in languages such as Chinese and Russian, on the other hand, are encoded using 16-bit Unicode USC-2. Depending on the language, the maximum number of characters that can be fitted into a single SMS message will be either 160 (1120 bits = 7 bits per character * 160 characters) or 70 (1120 bits = 16 bits per character * 70 characters). It is obvious then that the reason for the 160-character limit is twofold, owing to both the choice of the SS7 MAP signalling protocol and the implementation of the default character set [10]. There are advantages and disadvantages to any character set implementation. Morse code assigns short codes to the most commonly used letters,

making those easier to send. The drawback is that the longest character '0' takes 19 times longer to transmit than the shortest character 'E'. When the telegraph was mechanized, the focus switched to constant length codes whereby each character takes the same time to transmit. The smallest number that can encode 26 characters using a binary signalling system is 32 or 2^5 (two to the power 5) which means each character can be uniquely encoded using 5 bits. The French telegraph engineer Emile Baudot invented this system in 1870. Early teleprinters commonly used the Baudot system and if the designers of SMS had considered Baudot, then 224 characters per message (1120 / 5) , an increase of 40%, would instead have been possibles.

SMS handsets and modems can operate in either text or PDU mode. Text mode is an encoding of the underlying bit stream using GSM alphabets. PDU stands for protocol data unit and represents the way digital information is coded and structured when it is transmitted. If complete control of the data is required, then the text mode can be bypassed and the raw binary data can be directly manipulated in terms of ones and zeroes (or, more specifically, as hexadecimal strings) in PDU mode. Since binary data are verbose, PDU data are usually specified in terms of hexadecimal bytes. A normal 8-bit byte can be represented as 1111 1111, which can be written as FF in hexadecimal (1111 in binary = 15 in decimal = F in hexadecimal).

The transmission of a message can be broken down into two steps, namely, mobile-originated (MO) and mobile-terminated (MT) services. A mobile-originated service deals with transmitting a message from the sending phone to the SMS centre, while the mobile-terminated service is concerned with transporting the message from the SMS centre to the destination phone. The SMS-SUBMIT PDU relates to the mobile-originated service, while the SMS-DELIVER PDU relates to the mobile-terminated service. When control over raw data is required, both types of PDU must be addressed. To send a message, an SMS-SUBMIT PDU must be created, and to receive an SMS message, the SMS-DELIVER PDU must be interpreted. The main point is that PDU mode allows for the manipulation of SMS in virtually any way desired. The catch, of course, is that such a message is meaningless to a receiving handset unless it can process the manipulation; otherwise, the handset simply has a message that it does not understand and cannot display to the user in a meaningful way. In order to transmit a message this way, a custom-protocol stack layered on top of the normal SMS stack that is available to both the sender and the receiver is needed. This could be done by either inserting the code into the handset firmware or by encoding the message before sending it to the GSM modem and, on receipt, instructing the GSM modem not to interpret the message but rather to hand it over to the custom stack. Ideally, the stack would be adopted in the GSM specification, which would mean handset manufacturers would support the feature natively. To first demonstrate the protocol practically, however, a custom stack must be introduced and wrapped around the GSM modem interface.

This can be done with a PC running the stack and interfacing with the GSM modem over a physical serial link. The SMS specification supports this set-up through the Hayes set of AT commands [11].

Initially, when users had to type messages exceeding the 160-character limit, they would type one message, send it, then continue the conversation by typing the next message and send that. It was not long, however, before some of the handset manufacturers started to automate the process by allowing the user to type a long message in its entirety, press send and let the handset break the message into 160-character parts to send each individually. At this stage, there was no support for reassembling the message on the receiving side. The recipient received the parts, often out of order, and opened each of the parts individually to read it. Eventually, the idea of concatenated (or long) SMS was taken up officially in the GSM specification, which meant that handset manufacturers could implement functionality in a standard way. The concatenated SMS specification stated that the handset should label each of the parts with a sequence number, that is, the equivalent of "part 2 of 3", to allow the receiving handset to recombine the parts in the correct order in order to display the message to the user as a whole.

The solution for concatenated SMS builds on the core PDU structure and embeds the concatenated meta-information into bits that would otherwise be used for the text message payload. The concatenated meta-information (i.e. "part 2 or 3") is incorporated as a special 6-byte header called the concatenated SMS user datagram header (UDH). The header is present in every part of a concatenated SMS message, which reduces the storage space for the text message from 1120 bits to 1072 bits (1120 – 6 bytes * 8 bits per byte). Therefore, only 153 characters (1072 / 7 bits per character) can be fitted into each part of a concatenated SMS message. The binary data making up the PDU packets are transferred in byte-high, bit-low order. In other words, the higher-order bytes are transferred first, followed by the lower-order bytes. The bytes themselves are transmitted one bit at a time, from the lowest-order bit first to the highest-order bit. For example, the hexadecimal string 02AE would be transferred as 1010111000000010 as shown in Table 2.1.

	HEX	**BINARY**							
BYTE1	02	0	0	0	0	0	0	1	0
BYTE0	AE	1	0	1	0	1	1	1	0
		bit7	*bit6*	*bit5*	*bit4*	*bit3*	*bit2*	*bit1*	*bit0*

Table 2.1: PDU packets are transferred in byte-high bit-low order.

2.2 Compression and decompression

Text compression is the process of making a body of printed or written work more compact in order to minimise the space required for storage or transmission. The bit or binary digit is the basic unit of information storage and transmission in digital computing. Therefore, in computer science, text compression involves encoding the content using fewer bits than the number required to represent the message in its original state [12]. However, compressed data is not immediately useful and must first be restored by reversing the changes in a process called decompression. Compression involves two main steps, namely, modelling and coding. Modelling represents derived knowledge about the subject data and typically incorporates a redundancy study [13]. The resulting model and data are then fed into a coder, which encodes the data into a more compact form by applying the model. The coding part involves feeding the model and data into an algorithm for encoding. The algorithm reads the model and uses the contained domain context to calculate the best way of compacting the data. To decompress the data, these steps are reversed in that the model and compacted data are fed into an algorithm so that they can be decoded to produce the prototype source.

When air is compressed, the degree of compression is a result of the pressure applied. To compress air into a smaller volume, more pressure must be applied; similarly there is a trade-off that must be considered when compressing text. The design and selection of a particular scheme involves considering the achievable compression ratio against various factors in terms of acceptable distortion, processing power, memory requirements and time of execution. Text is usually compressed in such a way that the original message can be reconstructed exactly. This is called lossless compression. There are situations in which it becomes perfectly acceptable to lose some of the original representation in order to achieve a higher compression ratio. The popular MP3 audio format uses a lossy compression scheme to vastly reduce the bits required to store music tracks while still offering near-CD-quality listening. This reduction is achieved by sacrificing the precision of certain sounds occurring in the range outside what most people can discern [14]. Lossless compression allows the original information to be recreated exactly, without any loss of quality or precision. The disadvantage is that the resulting compression ratio will not be as high as that which can be achieved using lossy compression, through which some of the data can be discarded. Lossless compression typically involves some form of entropy encoding, which exploits statistical redundancy to make the data more concise while preserving the original precision. The idea is to replace repeating units of the data with shorter codewords. The units that appear most frequently are replaced with the shortest codewords, and the ones that appear least often are replaced with the longest codewords. A codeword is nothing more than a sequence of bits, the length of which equals the number of bits in a sequence. The major difference between the different schemes is the way in which they produce the statistical model from

which frequencies or probabilities are determined. The schemes all employ either a static or an adaptive model. Static models are those produced entirely before the encoding stage; the encoder receives the model and does not modify it in any way. Adaptive systems work differently, as the model changes during encoding in response to analyses of the growing dataset. In an extreme case, an adaptive system might start with a perfectly trivial or empty model, yield poor results and then adapt to compact the data dynamically better by performing a single pass or multiple iterations of introspection and compression.

Lossy compression followed by decompression does not restore the original data to exactly the same state. When the data are compressed, there is a net loss of quality or precision that cannot be recovered during decompression. While lossless compression is typically used for text and computer data files, it is very common to use lossy compression for rich media such as pictures (e.g. JPEG), music (e.g. MP3) and films (e.g. MPEG-4). The main advantage of lossy over lossless encoding is that much smaller encodings can be created while still remaining useful. Sometimes the quality difference between the original and the restored data is almost imperceptible. A naïve but illustrative example of lossy compression would involve storing the number 9.99999999 as 10, which is a reduction in character count of 80%. The original precision is lost, but the approximation is close. There are two main categories of lossy compression method, namely, transform and predictive methods. Transform codes take samples from a music track, for example, break it into parts, transform these in terms of a new basis coordinate and reduce the discrete values in a process called quantisation before entropy encodes the result. In predictive lossy compression, the next target sample is predicted on the basis of a previous result. The differential between the actual and predicted result is then quantised and encoded.

The branch of information theory called rate-distortion science deals with determining the amount of precision that may be sacrificed during lossy compression without rendering the result unusable. Dictionary-based compression is among the most popular forms of lossless data compression [15]. The data are broken up into non-overlapping units called phrases, and these are then mapped to shorter bit strings called codewords. The dictionary is the tool that provides the mapping between phrases and codewords. When compressing text, the simplest implementation of this scheme would involve replacing each word with a codeword representing the index of the word in a dictionary such as the *Oxford English Dictionary*. The representation of verbal information as single numbers can optimize main storage, peripheral storage, and data transmission [16]. In a large dictionary however, the index for a word can consist of more digits than the word it represents has characters. However, this could be offset somewhat by the advantage that words at the start of the dictionary have indices shorter than their corresponding words. The other drawback of this method is the sheer size of the

dictionary. If the dictionary were to be encoded along with the message so that the recipient would have it to decompress the text, then the compressed message might be significantly larger than the original input. Considering that the *Oxford English Dictionary* contains 59 million words and requires 540 megabytes of storage space, it becomes obvious why this approach is impractical. However, since the dictionary is static and not based on the content of the message, another option is to omit it from the encoded form if an agreement can be reached on the recipient having the dictionary on hand. However, there are methods that are more sophisticated than using words as the phrases to replace. The problem with words involves the sheer number of possibilities; encoding characters, for instance, reduces the size of the set significantly, and some dictionary-based methods are predicated on this approach. In fact, this is the single method used to represent text on computers. Computers only understand binary digits and cannot, for example, make sense of the concept "a" or "b" natively. The US ASCII Character Set, for example, uses a dictionary of 7-bit patterns to represent every character in the English alphabet. Larger sets such as Unicode UTF-8 use the same dictionary design and incorporate symbols not only from English but from all modern written languages by allowing each symbol to be represented by anything from 8 to 32 bits. This is a form of encoding, however, and not compression. Compression of a character would require representing that character with fewer bits than those required using the bit pattern from its character set. Dictionary size and the speed at which lookups can be made are the two trade-offs between cost and latency.

Huffman coding is a form of lossless, dictionary-based data compression using entropy theory based on the assumption that the input data consist of some symbols, be they characters or bit sequences, which occur more frequently than others [17]. Data that satisfy this assumption can be compressed quite well, while those that do not are better suited to other compression means. The assumption does, however, hold true for most text files and raw images. The algorithm first scans the data input, then identifies repeating symbols, and finally organises these into a frequency table sorted from most to least frequent. The entries from the table are then organised into a binary tree, the purpose of which is to derive a unique bit sequence of variable length for each of the symbols. The bottom-up layout of the tree ensures that the most frequently used symbols are assigned the shortest bit sequences, while the less frequent ones have longer sequences. The algorithm then makes a second pass over the original data, replacing each of the symbols with the bit sequence derived from the tree before also storing the frequency table in a compression header. During decompression, the frequency table is read from the header, and then, just as in compression, a tree is created to identify the mapping between bit sequences and symbols. The compressed data is then scanned, and each of the bit sequences is replaced with the corresponding symbol from the tree so as to arrive at the original data exactly. The most obvious question regarding this method of compression is why it is necessary to re-create the tree from the frequency table stored in the compression header rather than

just storing the tree instead of the table. The answer is that the bit sequences assigned to the symbols would take up more real estate in terms of storage than the frequency of each symbol. The main concept on which Huffman encoding is based is very simple and not even unique; it represents symbols with codewords that are shorter than their original encoding allows based on the frequency of the symbols. The cleverness of the Huffman method rests in the use of a bottom-up tree to find shorter codewords. It is for this reason that, even though the frequency table is stored in the compression header, it is known by a rather generic name, while the tree is crowned with the inventor's name, that is, the Huffman tree. A simple example can be used to illustrate Huffman encoding. Table 2.2 shows the frequency table for the text "aaaaaabbbbcc".

Symbol	Frequency
a	6
b	4
c	2

Table 2.2: Huffman frequency table for "aaaaaabbbbcc".

The next step is to build the Huffman tree. There are different ways to explain the algorithm: two instances being mathematical and logical. The logical method described next is easier to understand. Initially, there are no parents, only disconnected leaf nodes. The tree is built by repeatedly iterating over the existing nodes and finding the two nodes that have the lowest frequency number and are not yet a parent. The two nodes, once found, are then given a common parent node that is assigned a frequency equal to the sum of that of the children. This process is repeated over and over until a single parent can be placed at the top of the tree, unifying all the branches. This so-called “ultimate” parent node is called the root. Figure 2.1 shows the Huffman tree in line with this example.

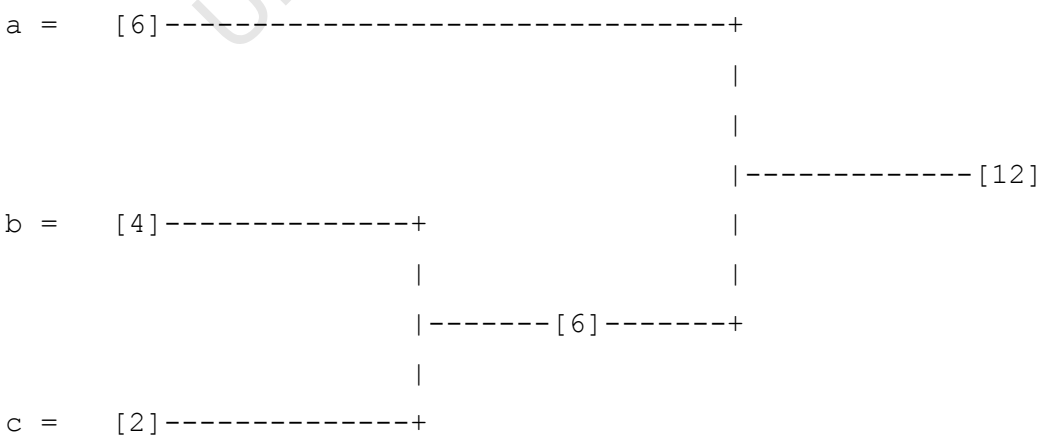


Figure 2.1: Huffman tree for "aaaaaabbbbcc" showing frequency numbering.

The next step is to traverse the tree from the root to each of the leaves, assigning a 1 to the path along every left branch and a 0 to the branch on the right as depicted in Figure 2.2.

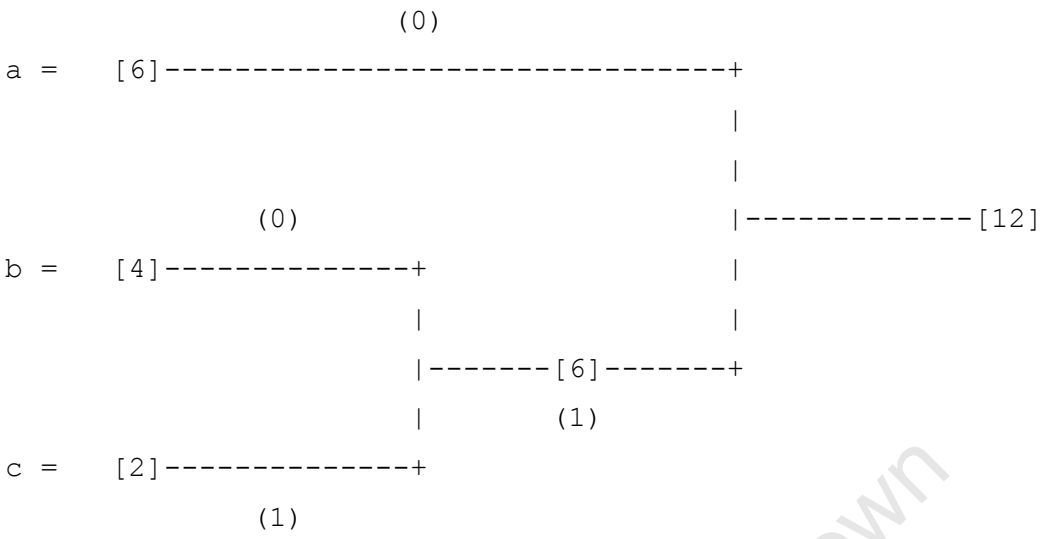


Figure 2.2: Huffman tree for "aaaaaabbbbcc" showing numbered paths.

The bit sequence assigned to every symbol is created by traversing the direct path from the root to the leaf assigned to the symbol and appending all of the 1s or 0s encountered along the way. Table 2.3 shows the codebook or dictionary with the substitution codes that will be used to represent each of the characters in the message. Figure 2.3 shows how the message is encoded by representing each of the characters by its corresponding codeword from the dictionary.

Symbol	Bit sequence = tree path from root
a	0
b	10
c	11

Table 2.3: Huffman codebook for "aaaaaabbbbcc".

a	a	a	a	a	a	b	b	b	b	c	c
0	0	0	0	0	0	10	10	10	10	11	11

Figure 2.3: Message encoding for "aaaaaabbbbcc".

The length of the code is inversely proportional to the estimated frequency of occurrence of the character in question; in other words, more common characters are represented by shorter strings of bits in comparison to less common characters, which employ longer bit strings. All of this is calculated using a binary tree, more commonly known as a "Huffman tree". Thus, to take an extreme example involving an SMS text message written in English, we can expect the letter "a" to appear far more regularly than the letter "z"; likewise, an "e" will appear more frequently than an "n" but potentially not as often as a space. The corresponding bit patterns will reflect this. The estimated frequency of the occurrence of characters can be determined in one of three ways. There can be a pre-agreed and therefore fixed character distribution frequency. The advantage of this is that streams of data (in our case, characters in a text message) that comply with the fixed distribution frequency improve the overall compression rate. The disadvantage lies in the possibility that an input stream of data may emerge that deviates significantly from the pre-agreed character frequency distribution. To avoid this, there is an alternative "dynamic" Huffman encoding method. In this scenario, a coder monitors and adapts the frequency distribution based on the appearance of previous characters in the bit stream during input processing. The decoder then generates the Huffman tree, which reflects the information processed in the bit stream. Gallager first showed showed that a Huffman tree with a distinguished node could be converted to another Huffman tree by swapping subtrees of equal weight [18, 19]. A distinguished node is one from which every other node on the tree can be reached without a loop. The conversion can be performed in time logarithmic to the number of nodes on the tree and without requiring structural change if the count on the distinguished node were to be increased. Knuth built on this idea by producing an algorithm that maintains a Huffman tree when leaf weights are decremented or incremented [20]. Vitter improved on the algorithm further by introducing a new system for numbering nodes corresponding to their level ordering [21].

The compressed size of a message encoded with a dynamic Huffman algorithm will usually be less than that obtainable using the original static algorithm, since the coding can be different or tailored to different places in the input stream. With small amounts of data, however, such as we may expect to find in an SMS text message, this comes at a price as a result of the byte space occupied by the compressor header, which is used to generate the character frequency distribution. As a third alternative, both methods can be combined so that there is a fixed frequency distribution that can then be amended by the coder should any significant deviations arise in the data stream. This is even less suited to short messages, however, unless one reduces the number of characters within the character frequency distribution list. Those characters that are less common are assigned a "special character" status when they do appear, and the coder adds them to the frequency distribution when appropriate. McIntyre and Pechura [22] showed that, for short messages, the dynamic and semi-dynamic methods are less effective than the static method, which uses a fixed coding tree for all messages. There are

methods such as arithmetic coding [23, 24, 25, 26] which are superior [27] in most respects to Huffman coding. However, the GSM 03.42 compression algorithm for text messaging services [28] requires the implementation of raw untrained dynamic Huffman coding only. This paper proposes an alternative method to that outlined in GSM 03.42 and therefore discussion and comparison will be limited to Huffman coding.

Chapter 3 - Related work

Textspeak is an abbreviated form of slang in which proper spelling, grammar and punctuation are ignored in favour of brevity, thereby allowing users to save on keystrokes while also reducing the size of the message. According to Döring [29], the challenges of a small screen, restricted keypad and 160-character limit has encouraged the evolution of textspeak as an even more abbreviated language than that which emerged prior to that in chatrooms and virtual worlds. The associated keystroke benefits are less important now that predictive texting is widely available, but textspeak does reduce message size and, as such, can be viewed as a form of user-performed compression. For example, vowels are often removed from existing words to create abbreviations such as "txt" for "text" and "pls" for "please." Common phrases may be reduced to acronyms, so that "laugh out loud" and "be right back" become "lol" and "brb," respectively. Words are also often replaced by similar-sounding spellings. For example, "see" becomes "c" and "you" becomes "u" so that "see you" becomes "cu". The same can be done with syllables so that "great" becomes "gr8". Textspeak can greatly reduce the size of a message and speed up typing; however, although SMS provides an informal environment where mistakes are acceptable, it may not appeal to everyone or be appropriate for all situations.

However, there has clearly been a need to shorten messages and, in 1997, Vodafone undertook a study to investigate the way handsets might compress SMS messages. Vodafone's approach focused on using Huffman encoding to compress the SMS text prior to transmission and required the compression stack to be installed on the sending and receiving handsets. This method used a variation of the standard Huffman algorithm called dynamic or adaptive Huffman encoding, which compresses data as it is transmitted. The difference between the two methods is that standard Huffman encoding requires two passes over the data, whereas adaptive Huffman uses a single pass. Adaptive Huffman is faster to perform, but it is not as optimal as standard Huffman encoding in terms of the compression ratio that can be achieved. Using this method, Vodafone discovered that they could increase the number of characters per SMS message to 200. Additionally, they extended the algorithm further to incorporate the use of a static dictionary for business English. The dictionary codewords consisted of a list of keywords of up to 255 characters that could be replaced in the original text to further increase compression efficiency. With all of the options enabled, the number of characters per message was extended to 240, an increase of 50% [30]. The dictionary option supported English text only.

In 1998, the European Telecommunications Standards Institute extended the GSM specification with official support for SMS compression based on the work pioneered by Vodafone but enhanced with

further functionality. Unlike the Vodafone implementation, GSM 03.42 not only supports English but also western European languages such as German, Italian, French, Spanish, Dutch, Swedish, Danish and so on. At the time of writing, the specification has only been implemented for English and German, while support for the remaining western European languages is pending completion. The specification required only that untrained, adaptive Huffman compression be included in any implementation purporting to support compression. Character grouping is an optional feature whereby characters that are expected to appear together are grouped such that transitions are signalled not between individual characters, but between groups of characters. The net result is a smaller Huffman tree together with an increased compression ratio. The tree for the text "abcABC" would thus not contain characters for both lower-case and upper-case characters but instead for the lower-case characters only and then a special non-printable character to signal the transition to upper-case. The stream would thus be encoded as "abc[UpperCaseTransitionSignal]abc". The savings here are not in the payload but in the tree that would be freed from storing nodes for "A and B and C". The algorithm also optionally supports keyword substitution through the use of language-specific dictionaries. The dictionary for each language supports 128 static entries for common words. The presence of a keyword substitution is signalled with a special keyword preceding the substitution. A keyword is encoded using 10 fixed bits. If, for example, the dictionary contained only the words "this" and "sunday", then the text "i'll see you this sunday" would be encoded as "i'll see you [KeyWordSignal][10 bits = this][KeyWordSignal][10 bits = sunday]". The final option supported is punctuation processing, which, if used, distorts the text so that the message does not resemble the original exactly. Punctuation processing removes leading and trailing white spaces from the input stream and reduces otherwise redundant spaces to a single space. On encoding, the first character of every sentence is converted to lower case, and the last character of the stream is dropped if it is a full stop. On decoding, the cases are restored except for the final full stop. In other words, when punctuation processing is used, GSM 03.42 constitutes a form of lossy compression.

CleverTexting [31] is a commercial, patent-pending SMS compression scheme from an Indian company by the same name. The compression scheme is implemented as a Java midlet that is installed on sending and receiving handsets. CleverTexting was released in 2009 and can achieve a 30 to 40% increase in text length, extending the number of characters in an SMS to 224. The company website does not fully describe the compression scheme, but does explain a custom implementation is created for each of the supported languages and that the punctuation such as spaces, commas and full stops are not removed.

The Technical University of Berlin and Aalborg University in Denmark have researched compressing short messages using prediction by partial matching (PPM). PPM is categorized as a form of adaptive

statistical compression that builds a context model of the input stream to predict future symbols. The probability of each symbol is passed though an arithmetic coder to compute the compressed sequence of bits. Arithmetic coding does not replace each symbol with a code, but instead encodes the entire message into a single number which will be a fraction n where ($0.0 \leq n < 1.0$). The processor is novel in that it does not use the dictionary to store the single character arrays and their probability. Instead, it uses a single data array where each element consists of two bytes: The first byte contains a symbol count and the second a parity check byte. The single elements are accessed by a specific hash function that assigns each character array an element of the data array. Collisions are detected by a parity check of the hash function input and the parity byte of the mapped element in the data array. This data model, together with functions to compute the complete statistics of the requested symbol, form the context model. This technique increases the length of an SMS by 50 to 55%, allowing the number of characters in an SMS message to be increased from 160 characters to 320–340 characters [32,33]. The researchers have applied for a patent on the work with the help of the Patent and Contract Unit at Aalborg University and this is currently pending. The team consists of Stephan Rein, Clemens Guehmann and Frank Fitzek. Frank Fitzek co-founded Acticom GmbH in Berlin, which is a leading supplier of protocol stack software for companies such as LG Electronics, Novell and VTT and offers SMS Zipper as a commercial product based on the published work: SMS Zipper is installed as a Java application on the sending and receiving handsets, which must support J2ME. SMS Zipper uses an external model to support specific languages, which allows the model to be tailored to a specific language in order to yield the best possible results. It also allows the stack to be easily expanded to support additional languages. At the time of writing, SMS Zipper supports English, German, Danish and Italian. In [32], Rein, Guehmann and Fitzek state that, to their knowledge, their paper is the first to combine lossless short message compression with a low-complexity context modelling scheme.

The area of text compression has been well investigated, but little research has been done on its application to the domain of mobile text messaging. In addition to compressing short messages, there is the challenge of encoding the data in a way that is compliant with the GSM specification for SMS PDUs. Nakayama [34] proposes a method whereby, unlike conventional paradigms that send messages in the form of character sequences, key code sequences are used that reflect the user's typing history to author the message. The key-code representation can be as efficient as 4 bits per key code. Experiments using the Canterbury corpus and the optimal dictionary have shown that key-code representation requires 2.95 fewer bits per character compared to the conventional GSM 03.38 representation. Using this method, each character can be encoded in 4.05 bits. After evaluating LD-based compression, we will revisit the methods discussed here to compare the resulting compression ratios.

Chapter 4 - Design and implementation

4.1 Algorithm

We propose to implement a software algorithm for compressing SMS messages. The core method of coding involves the use of a bespoke dictionary containing short keywords to represent English words. Instead of sending an SMS message as normal text, the message is processed with the English words being replaced with shorter keywords from the dictionary. In other words, if we wish to send the message "Hello World" and using the dictionary from Table 4.1, we could encode the message as "1 2".

English Word	Replacement Keyword
Hello	1
World	2

Table 4.1: Example dictionary showing how shorter codes can be used to substitute for longer sections of text (in this case words).

This is, of course, a very naive implementation, but it does demonstrate the fundamental concept, namely, the replacement of English words with much shorter indicators. In the above example, the number of characters was reduced from 11 (including spaces) to 3, which is a drastic reduction in size. To accomplish this type of encoding, the dictionary should contain as many entries as possible. However, there will be cases in which certain words are not found in the dictionary. In such cases, the word will not be substituted but rather kept as is. If we consider the message "Hello Again World" using the same example dictionary as before, then we lack a dictionary entry for "Again". In other words, we do not have a so-called “hit” in the dictionary, and the resulting encoding will look like "1 Again 2". The reduction is not as drastic this time, but it is still significant. This means that we can encode any text message and not merely messages in which all the words are found in the dictionary. This is the fundamental basis of the coding mechanism proposed in this study. Of course, the characters making up the word "Again" would still need to be encoded according to a character alphabet. To avoid fracturing the implementation to accommodate both a word dictionary and a character alphabet, the two structures are combined so that the lossy dictionary-based dictionary contains entries for characters and words. There are also special signalling entries to indicate conditions such as "Yes, this message was encoded using our algorithm". Further discussion of the signalling entries is deferred until a later section. Additionally, the keywords are not actually textual as described above, but are rather unique binary sequences. On the receiving side, the message must be decoded

again. This decoder considers the input stream, parses out the symbols and then looks up each symbol against an exact copy of the dictionary that was used on the sending side. The binary symbols are replaced with their corresponding textual entries. Some of the symbols are replaced by word entries, while others are replaced by character entries. Table 4.2 and 4.3 show the steps involved to respectively compress and decompress an SMS message using the LD-based method..

Step	Name	Description
1	Preprocessing	Eliminate redundant whitespace. Eliminate non-printable characters. Convert all text to lowercase.
2	Parsing	Perform lexical analysis of input stream and parse text into words and punctuation characters.
3	Add compression header	A special compression header is constructed using a signalling entry from the dictionary.
4	Dictionary replacement	Words from the message are replaced with keywords from the dictionary. Words not found in the dictionary are encoded one character at a time using binary keywords from the dictionary.
5	PDU structuring	The binary stream of keywords is packaged according to the rules for a SMS SUBMIT PDU.

Table 4.2: Algorithm outline for compressing an SMS message using LD-based encoding.

Step	Name	Description
1	PDU extraction	Extract the data stream representing the message from the PDU DELIVER PDU.
2	Recognition	Inspect the first byte of the data stream to determine whether it was encoded using LD-based compression. If not, then abort further processing and treat as a normal SMS.
3	Dictionary replacement	Replace binary keywords in data stream with textual entries from dictionary. Some of the keywords will map to word entries, others to character entries.

Table 4.3: Algorithm outline for decompressing an LD-based SMS message.

4.2 Dictionary

In designing the dictionary, care should be taken to ensure that, during encoding, the hit ratio for matching words in the SMS message to entries in the dictionary is as high as possible. The more words there are that can be replaced with short codewords from the dictionary, the better the compression result will be. The dictionary must thus contain those words that will be used most frequently in SMS messages. One way to accomplish this would be to analyse thousands and

thousands of SMS messages and build up a statistical model indicating the frequency at which words occur. The dictionary would then be created by adding words from the statistical model, starting with the most frequently occurring words until all available slots have been filled. The problem with this approach is that it is hard to find such an archive of SMS messages. Another approach might be to take a literary corpus of written work and build the statistical model from that. There are indeed sufficient books available in the public domain to follow this approach. However, the language used in SMS messages tends not to resemble that found in books but rather is generally patterned like the informal flow of spoken speech. According to Lingley [35], written speech is organised and transactional, while spoken speech is typically unplanned, less structured and interactive. The researchers in this study decided to create a statistical model using spoken speech as the training medium. In order to do so they took scripts from television shows and films, which are often freely available on the Internet. In computational linguistics, this type of statistical model is called a frequency list. In simple terms, a frequency list is a sorted list of words and their frequencies; the frequency indicates the number of occurrences in a given corpus, which is, in this case, television and film dialogue.

Table 4.4 show the ten most common words in the English language as rated by the *Oxford English Corpus* [36].

Rank	**Word**
1	the
2	be
3	to
4	of
5	and
6	a
7	in
8	that
9	have
10	I

Table 4.4: Ten most common words according to the Oxford English Corpus.

A similar study was performed by the open content group Wiktionary, using collections of TV and film scripts and transcripts mainly downloaded from the Internet. Table 4.5 shows the most common words as indicated by Wiktionary [36].

Rank	Word
1	you
2	I
3	to
4	the
5	a
6	and
7	that
8	it
9	of
10	me

Table 4.5: Ten most common words as indicated by Wiktionary.

There is very little difference between the lists, and significantly, there are very few differences when comparing the 100 most common words, as the same words appear with only slightly different ranks. For instance, the words "be", "in" and "have" are missing from the Wiktionary top-10 list but appear instead ranked at 25, 13 and 18, respectively. The researchers used the frequency lists from the Wiktionary project as the basis for constructing the dictionary only because the entries are expected to align slightly better with regular spoken dialogue. The Wiktionary project counted 29,213,800 words of transcript dialogue. Hyphenated words were broken down so that, for example, "happy-juice" was counted as "happy" and "juice." Apostrophes were stripped from words, unless they were entirely contained within word characters. For instance, "'cause" would be counted as "cause", but "don't" would be counted as "don't". All of the words were converted to lower case, so "He" and "he" would both be counted as "he". The only exception is "I", which always appeared in upper case. Verbal expressions such as "phew" and "brr" were counted, but they only entered the lower-frequency end of the list.

There are three types of entry in the dictionary, namely, signalling symbols, character symbols and word symbols. Signalling systems indicate special processing conditions. For instance, the decoder algorithm reads the first byte of the input stream to determine if the LD-based compression instruction is set. This instruction is a signalling symbol that indicates to the decoder that the message was indeed encoded using LD-based compression and can be decompressed safely. If the signalling symbol is not set, then the input stream is treated as normal, uncompressed SMS data. The dictionary can accommodate exactly 32,768 entries. This is because the coder reads and writes data in either 8- or 16-bit chunks and uses the highest-order bit of the highest-order byte of every chunk to indicate the size of the chunk. An 8-bit chunk would be stored as 0xxxxxxx, and a 16-bit chunk would be

stored as 1xxxxxxxxxxxxxxx. If we bear in mind that the value represented in 8 bits by 0xxxxxxx is equivalent to the 16-bit value represented by 00000000 0xxxxxxx, we can create a continuous range of values from 00000000 00000000 to 11111111 11111111. There is a catch, however, in that the first bit cannot be used, since it must indicate the size of the chunk; this leaves 15 bit positions in the lower order. The binary number 111 1111 1111 1111 can be written as 0111 1111 1111 1111. This means that the range of slots in the dictionary will be numbered from 00000000 to 01111111 11111111, which, in decimal notation, is 0 to 32,767, for a total of 32,768 places.

Before seeding the dictionary, the Wiktionary lists were further processed by removing all words that consisted of a single character, such as "a" and "I", as such words already appear in the dictionary as single character entries instead of word entries. In the end, the dictionary takes the form illustrated in Table 4.6.

Number in decimal	**Symbol**	**Symbol type**	**Bits to encode**
00000	<LD-based compression indicator>	signal	7
00001	<sp>	character	7
00002	!	character	7
...	...	...	...
00040	a		7
00041	b	character	7
...	...	...	...
00070	you<sp>	word	7
00071	to<sp>	word	7
...	...	...	...
00126	at<sp>	word	7
00127	how<sp>	word	7
00128	got<sp>	word	15
00129	there<sp>	word	15
...	...	...	...
16418	you	word	15
16419	to	word	15
...	...	...	...
32766	brr	word	15
32767	grr	word	15

Table 4.6: Partial extract from LD-based dictionary.

The dictionary (partially shown in Table 4.6) contains only lower-case entries. This simplifies the problem of addressing different permutations of words such as "The", "THE" and "the". If all permutations were to be accommodated in the dictionary, then we would quickly run out of space and far fewer unique words could be supported. This means that the input stream has to be converted to lower case prior to encoding and that the original case will not be recovered upon decoding. It is this aspect that makes this encoding "lossy", but this is also the reason that we are able to achieve a relatively high compression rate. Furthermore, it takes 7 bits to encode a space character, as denoted by <sp> above. Since most words are followed by a space, this is a significant waste of space in that the number of spaces will usually be equal to 1 less than the number of words in the message. The dictionary contains an optimisation whereby all of the words are double encoded, once followed by a space and once without. In other words, the word "you" appears in the dictionary as both "you" and "you<sp>". This obviously cuts the number of unique words that can be accommodated in the dictionary in half, but with an sufficiently large dictionary this is not a problem. The LD-based dictionary stores more than 16,000 of the most commonly used English words in 316 Kb. The Oxford English Corpus indicates that English consists of a small number of very common words, a larger number of intermediate ones and an indefinitely long “tail” of rare terms [37]. Nation [38] estimate that a native English speaker would need to know around 5,000 words in order to read a novel written for teenagers. This type of novel was selected because it is deemed to be a good example of an accessible work of literature. In 2006, Nation ISP published the results of a very detailed study on how many words are needed for reading and writing at different skill levels (shown in Table 4.7).

Question	Answer
How many words do you need to read a novel?	2,000 words for 87.83% coverage 4,000 words plus proper nouns for 94.8% coverage 9,000 words plus proper nouns for 98.24% coverage proper nouns account for 1.53%
How many words do you need to read newspapers?	2,000 words for 83% coverage 4,000 words plus proper nouns for 95% coverage 8,000 words plus proper nouns for 98% coverage proper nouns account for 4.55% to 6.12%
How many words do you need to read graded readers?	2,000 words for 91.20 % coverage 2,000 words plus proper nouns for 96.75 % coverage 3,000 words plus proper nouns for 98.86 % coverage proper nouns account for 5.55%
How many words do you need to know to be familiar with most words in a children's movie?	4,000 words plus proper nouns for 96.70% coverage 7,000 words plus proper nouns for 98.08% coverage proper nouns account for 1.47%
How many words do you need to cope with an unscripted talk-back interview?	2,000 words for 89.41% coverage 3,000 words plus proper nouns for 96.52% coverage 6,000 words plus proper nouns for 98.26% coverage 7,000 words plus proper nouns for 98.62% coverage proper nouns account for 1.29%
How many words do you need to cope with unscripted conversation?	2,000 words for 89.35% coverage 3,000 words plus proper nouns for 96.03% coverage 6,000 words plus proper nouns for 97.67% coverage 7,000 words plus proper nouns for 97.95% coverage proper nouns account for 1.03%

Table 4.7: How large a vocabulary is needed for reading and listening?

The conclusion is that 8,000 to 9,000 words are needed for reading and writing and 6,000 to 7,000 words are needed for speaking and listening in order to understand 98% of content. The dictionary should thus contain at least the 9,000 most common English words in order to approach a 100% hit ratio, but in fact it contains the first 16,000 most common words.

4.3 Keyword substitution

The entries from the dictionary are all keyed against a binary pattern consisting of either 7 or 15 bits. Entries 0–127 are stored using 7 bits, and those from 128–32,767 are stored in 15 bits. During encoding, an extra bit is added just prior to writing the entry to indicate whether the entry itself is stored in 7 or 15 bits. A simplified version of the coder, which ignores signalling entries for the sake

of explanation, would encode the text "I love summer" according to the mapping shown in Table 4.8. During transmission, the mapping will be used to produce the binary stream illustrated in Figure 4.1.

	i	**<sp>**	**love<sp>**	**summer**
dictionary index (dec)	48	1	179	17505
dictionary index (bin)	0110000	0000001	000000010110011	100010001100001

Table 4.8: Encoding "I love summer" with the LD-based algorithm.

0	0110000	0	0000001	1	000000010110011	1	100010001100001

Figure 4.1: Binary stream for "I love summer" rendered by LD-based algorithm.

Table 4.9 shows hows the binary stream would be decoded on the receiving side.

Bits	**7-bit flag**	**15-bit flag**	**Symbol**
0	x		
0110000			i
0	x		
0000001			<sp>
1		x	
000000010110011			love<sp>
1		x	
100010001100001			summer

Table 4.9: Decoding the LD-based binary stream for "I love summer".

4.4 The prototype

A working proof of concept was created to test the theory behind the code design, as well as to help identify problems in the design. The first step was to generate the dictionary. Generating such a large codebook by hand would have been a slow, error-prone process, and so instead it was done using a combination of scripting and programming. Most of the prototype was implemented in OpenJDK 1.6 Java accompanied by Bash front-end scripts. True to the Unix philosophy, the prototype was written as a combination of various parts or libraries. Libraries, all created in Java, were created to (1) accept a text message from the command line; (2) compress the message using the LD-based routine; (3) encode the compressed message into an SMS PDU; and (4) submit the PDU to the GSM modem. A

Siemens TC35i terminal (shown in Figure 4.2) provided the GSM interface for sending and receiving SMS messages.

Figure 4.2: Workstation showing Siemens TC35i and aerial (circled).

The TC35i can be instructed using serial AT commands and is fully compliant with GSM 07.05 for SMS, which makes it straightforward to implement a driver using only GSM documentation. The terminal connects to a workstation running GNU/Linux kernel version 2.6.28-13 by way of a ch341-uart converter cable mounted on /dev/ttyUSB0. The PDU is transmitted to the terminal via port /dev/ttyUSB0 with the help of a driver that creates the necessary AT commands for pushing the PDU , as well as the open source RXTX library for serial line communication.

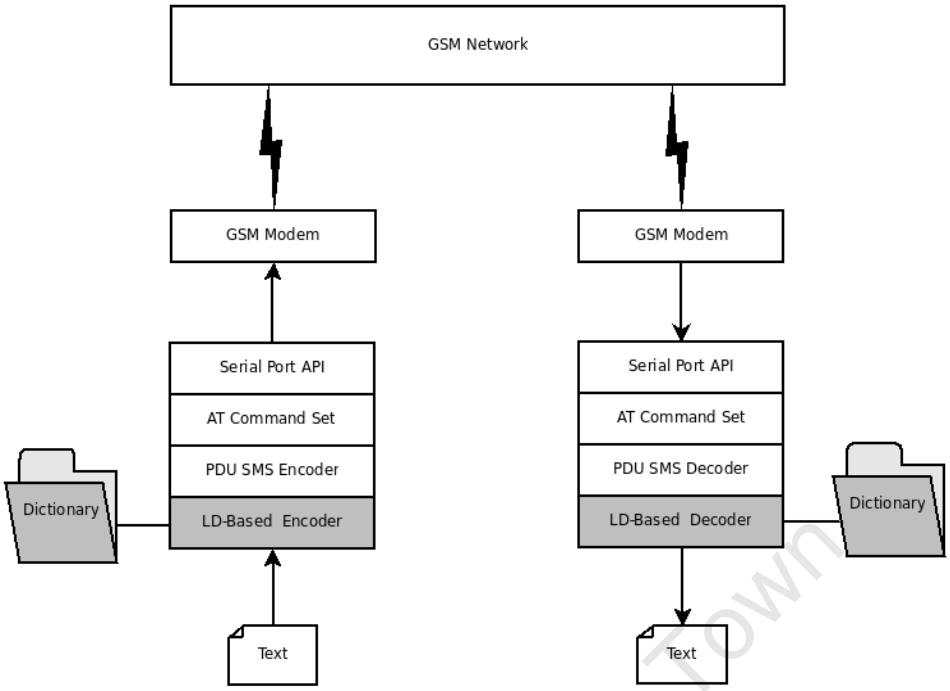


Figure 4.3: Prototype stack.for sending and receiving messages.

Figure 4.3 illustrates, at a high level what the coding and communication stack looks like for the sender and receiver. The code for the prototype is distributed along with this dissertation and includes data (i.e. novels and frequency lists) and scripts for generating the dictionary and building the prototype, as well as scripts for sending and receiving compressed SMS messages for running all the experiments. In this way, these experiments can be repeated objectively in order to generate reports on individual experiments, mine data from various experiment reports and present findings in a tabular form. There are also scripts for parsing the tabular data and generating Gnuplot graphs. Essentially, all the experiments and findings presented in the dissertation can be repeated in order to verify the results, study the source code and verify the logic involved.

Chapter 5 - Results and discussion

Public domain texts (shown in table 5.1) were taken from Project Gutenberg and then analysed against the dictionary to determine how much of the content is covered. By scanning every word in the text and tabulating the number of words that also exist in the dictionary, we are able to describe the coverage in terms of the hit ratio whereby a "hit" constitutes a word from the text that also exists in the dictionary. The public domain texts were analysed as is, in other words, unaltered from the original downloaded copies, which meant they included notes not present in the original printing such as disclaimers and terms of use added later by Project Gutenberg.

Text	**% unique hit ratio**	**% coverage hit ratio**	**Bits per character**
Dracula	58.16	90.14	4.01
Emma	59.69	91.67	4.03
Frankenstein	60.20	88.30	4.11
Monte Cristo	44.95	90.75	4.19
Origin of Species	45.75	86.23	4.28
Paradise Lost	45.81	85.77	4.50
Price and Prejudice	60.79	93.34	4.01
War and Peace	43.56	91.71	4.08
War of the Worlds	60.29	86.59	4.26

Table 5.1: Evaluating the LD-based dictionary for coverage against public domain novels.

There is a subtle distinction between the unique hit ratio and the coverage hit ratio shown in Table 5.1. The unique hit ratio indicates the percentage of unique words that also appear in the dictionary, whereas the coverage hit ratio indicates the total number of words appearing in the dictionary. A strong unique ratio indicates that the dictionary has a large vocabulary sufficient to cover many words, even if some of those words might only appear once in the text. The unique hit ratio is not a good indicator of how well the dictionary will perform, as there is little benefit to including scarcely used, exotic words. The more important metric is the coverage hit ratio, as this indicates how much of the total content of the text can be encoded against the dictionary. While the unique hit ratio fluctuates greatly between the different texts, the coverage hit ratio is more regular and predictable. A text such as Darwin's *Origin of the Species* is expected to contain many scientific and domain-specific words, which would not constitute the larger part of a vocabulary, and this is reflected in the rather low unique hit ratio obtained. Despite being a scientific text, however, the majority of the words

appear in casual speech, and words such as "the" and "and" appear more often than the scientific ones, resulting in a sufficiently high coverage hit ratio. In other words, while the dictionary contains only 45.75% of the unique words in *Origin of the Species*, it can be used to compress 86.23% of the content. The coverage hit ratio is relatively constant, ranging from a low of 85.77% to a high of 91.71%. The compression ratio achieved ranges from 4.50-4.01 bits per character, or 35.71- 42.71%. At first, the compression ratio achieved does not sound very impressive, and indeed it is not, since the compression algorithm is not tailored to give the best compression for large texts such as the above. A method such as GZIP, for instance, would provide a much better compression ratio. However, the compression method is more effective than GZIP or some of the other popular algorithms when applied to small texts such as the ones for which the LD-based method is intended.

Table 5.2 shows the results of compressing the full 61,313 characters of text from *Paradise Lost.* The conclusion is that LD-based compression is not well suited for compressing large datasets.

Algorithm	**Typical file extension**	**Kilobytes**	**% difference**
Plain US-ASCII	-	420.1	reference
Plain UTF-8 text	-	479.0	+14.02
BZip2	bz2	148.0	-64.77
Comic Book ZIP	cbz	196.2	-53.30
Gnu Zip	gzip	196.1	-53.32
Lempel-Ziv-Markov chain-Algorithm	lzma	167.1	-60.22
Zip	zip	196.2	-53.30
Huffman	-	216.5	-48.46
LD-based	**-**	**263.2**	-37.35

Table 5.2: Compression results for the epic poem Paradise Lost.

Previously, compression was measured using non-standard files, which raised the possibility that the file selected might unfairly favour the particular algorithm being tested. In order to compare the compression results from two different algorithms, the same baseline should be used to ensure that the comparison is like for like and unbiased. The Canterbury Corpus (Table 5.3) was presented in 1997 as a replacement for the older Calgary Corpus as, after 10 years of use, the latter had started to reveal several shortcomings. The biggest problem with the Calgary Corpus was that it was compiled from a rather arbitrary body of work. The authors of the Canterbury Corpus, on the other hand, took care to ensure that the inclusion of a document in the corpus was justifiable as a means to indicate compression efficiency. The criteria for choosing the Canterbury Corpus included that 1) the

documents be representative of the type of files that would be likely compression targets in real-world situations; 2) the files be of moderate size to make distribution a non-issue; and 3) the corpus be available to all wishing to use it. This last point was addressed by limiting the corpus to documents freely available from the public domain. The Canterbury Corpus also incorporated contemporary formats such as HTML and, moreover, was distilled from a pool of 800 candidates. These candidate documents were divided into 11 predefined categories, and within each category the most representative candidate was selected based on a scatter plot of file size before and after various compression methods were applied. The file that delivered results closest to the regression line was selected from every category to become a de facto part of the corpus.

File	Category	Description	Bytes
alice29.txt	text	English text (*Alice in Wonderland*)	152,089
asyoulik.txt	play	Shakespeare (*As you like it*)	125,179
cp.html	html	HTML source	24,603
fields.c	Csrc	C source	11,150
grammar.lsp	list	LISP source	3,721
kennedy.xls	Excl	Excel Spreadsheet	1,029,744
lcet10.txt	tech	Technical writing	426,754
plrabn12.txt	poem	Poetry	481,861
ptt5	fax	CCITT test set	513,216
sum	SPRC	SPARC Executable	3,824
xargs.1	man	GNU manual page	4,227

Table 5.3: Contents of the Canterbury Corpus.

The LD-based algorithm is designed specifically for compressing English text, and so we will focus exclusively on the compression of alice29.txt.

Algorithm	Bits per character
bred-r3	2.55
ppmD5	2.20
szip-b	2.24
bzip-9	2.25
bzip-6	2.25
szip	2.25
ppmD7	2.26
bzip2-9	2.27
bzip2-6	2.27
ppmC-896	2.30
ppmD3	2.31
dmc-50M	2.38
dmc-5M	2.38
dmc-16M	2.38
ppmCnx-896	2.39
bzip-1	2.40
bzip2-1	2.42
gzip-b	2.85
huffword2	3.09
yabba-d	3.18
compress	3.27
ppmC-56	3.29
gzip-f	3.43
ppmCnx-56	3.57
srank-d	3.66
LD-based	**3.85**
gzip-d	3.86
char	4.59
pack	4.62
lzrw1	4.94
yabba512	5.31
cat	8.00

Table 5.4: Compression ratio achieved on alice29.txt from the Canterbury Corpus.

Table 5.4 outlines the results from compressing the Canterbury Corpus. The outcome in this instance follows that from compressing *Paradise Lost*; that is, LD-based compression is not very effective for

large-sized documents. However, this coding method was not designed to be effective for such documents, and importantly, the outcome is quite different when we compare the compression results for a small text such as:

Thanks! Hope you have great Xmas too! What you up to these days? Still in London? Can't believe I've been back in NZ for nearly 18 months, but I'm still loving every minute of it! (Ref# 0179)

The above message is 179 characters long and about the length we can expect for a typical SMS message. Table 5.5 shows the results of compressing this message with some of the popular compression methods.

Algorithm	**Typical file extension**	**Bytes**	**% difference**
Plain US-ASCII	-	157	reference
Plain UTF-8 text	-	179	+14.01
BZip2	bz2	174	+10.82
Comic Book ZIP	cbz	306	+94.90
Gnu Zip	gzip	177	+12.73
Lempel-Ziv-Markov chain-Algorithm	lzma	169	+7.64
Zip	zip	306	+94.90
Huffman	-	148	-5.73
LD-based	**-**	**75**	-52.22

Table 5.5: Result of compressing message Ref# 0179 with different methods.

The methods perform very well with larger datasets, which is the domain for which compression is typically required. That is, it aims to reduce large datasets to small ones. However, these methods do not fare so well with small datasets. The LD-based method was designed to be effective with small texts, and so it is much more effective in this range but less so for larger datasets. It is significant how much better LD-based encoding fares compared to Huffman encoding, especially since Huffman encoding is the only compression method officially supported in the SMS specification. For large datasets, we can expect Gnu Zip to outperform Huffman encoding as is evident from the experiments discussed previously, but in the case of small messages, Huffman encoding was the only standard algorithm that provided any savings at all, suggesting why it was chosen as the basis for GSM 03.42. However, the use of LD-based encoding resulted in a reduction in message size of over 50%. Notice also that, while the compression ratios achieved for methods such as Huffman and GZip encoding

vary greatly depending on the size of the message, LD-based encoding is more consistent. When novels were compressed, the average reduction in size was around 40.52%.

As Huffman compression is the only method supported in the GSM specification, we are especially interested in comparing LD-based and Huffman encoding. To this aim, eight short messages were created and a prototype was employed to send and receive the messages, as well as to report the differences between standard uncompressed SMS, Huffman-encoded SMS and LD-based encoded SMS. Table 5.6 lists the messages used in testing.

Message	Length
Hello World!	0012
The quick brown fox jumps over the lazy dog	0043
Now is the time for all good men to come to the aid of the party	0064
Thanks! Hope you have great Xmas too! What you up to these days? Still in London? Can't believe I've been back in NZ for nearly 18 months, but I'm still loving every minute of it!	0179
Yes, but to be honest, when I am working on a problem I never think about beauty. I only think about how to solve the problem. But when I have finished, if the solution is not beautiful, I know it is wrong	0205
Hey mate, how are you? Meant to email you after a trip to cape town to let you know i'd finally seen your beautiful city. What are you doing in london when you can call cape town home? Was a nice change from life in the slums too. Hopefully coming over for a wedding in April next year - will keep you posted. And would love you to come visit Australia!	0353
And so it was indeed: she was now only ten inches high, and her face brightened up at the thought that she was now the right size for going through the little door into that lovely garden. First, however, she waited for a few minutes to see if she was going to shrink any further: she felt a little nervous about this; 'for it might end, you know,' said Alice to herself, 'in my going out altogether, like a candle. I wonder what I should be like then?' And she tried to fancy what the flame of a candle is like after the candle is blown out, for she could not remember ever having seen such a thing.	0600
We understand it still that there is no easy road to freedom. We know it well that none of us acting alone can achieve success. We must therefore act together as a united people, for national reconciliation, for nation building, for the birth of a new world. Let there be justice for all. Let there be peace for all. Let there be work, bread, water and salt for all. Let each know that for each the body, the mind and the soul have been freed to fulfill themselves. Never, never and never again shall it be that this beautiful land will again experience the oppression of one by another and suffer the indignity of being the skunk of the world. Let freedom reign. The sun shall never set on so glorious a human achievement!	0723

Table 5.6: SMS messages used in testing.

The results for LD-based compression of the messages listed in Table 5.6 were evaluated with the aid of the prototype; the results in each case were compared to that obtainable through Huffman encoding.

Ref# 0012	
Message	Hello World!
Decompressed message	hello world!
Characters	12
Hit ratio	100%
Words not found in dictionary	NA - All words found in dictionary

Result	**Uncompressed**	**Huffman**	**LD-based**
Bits	84	160	40
Bits per input char	7.00	13.33	3.33
Transmission bits	208	280	168
Transmission bits per input char	17.33	23.33	14.00
Number of SMS messages	1	1	1
Characters per SMS	12.00	12.00	12.00

Table 5.7: Results of encoding and sending SMS message Ref# 0012.

Table 5.7 shows a summary of results from running the test for Ref#0012. The full, line-by-line, log is attached to Appendix A. The GSM terminal was mounted on /dev/ttyUSB0 and the message "Hello World!" sent to 07894555501. Next, the AT driver's log shows the commands issued to send SMS-SUBMIT PDU containing the LD-based payload. The same modem was in turn used to receive the SMS message, which means that the actual phone number for the SIM in the GSM terminal is the same as the number to which the message was sent. This was done to eliminate the expense of buying a second terminal. To allow the message time to be delivered from the GSM network, a 60-second pause was included before issuing the AT commands for checking for unread messages. In fact, the command issued did not actually ask for unread messages, as there is no such command. Instead, all messages were retrieved, and then each was inspected by checking for a bit flag that indicated whether the message had been read or not. To avoid repeatedly downloading messages that had already been read, the researchers introduced a little hack whereby once the most recent unread messages were obtained, the script issued AT commands to delete all messages on the terminal. This

meant that the researchers started with a so-called “clean slate” so that, following the next sent message, only the latest messages were retrieved. Note that these peculiarities do not appear to affect the outcome of this analysis and were added to avoid capturing log output for messages in which we were not interested for the sake of the experiments.

The unread message was then decoded, and the LD-based payload was read from the SMS-DELIVER PDU. The payload was decompressed, and the message was displayed. A quick inspection shows that although the original message was sent as "Hello World!", the message that was actually sent and received was the lower-case equivalent "hello world". Other than the change in case, the message was exactly the same. The summary at the end of the output shows that all of the words in the message were found in the dictionary (i.e. 100% hit ratio); the summary also lists the index rank at which each of the words were found in the dictionary as well as the compressed hex and binary stream for each word. Notice that the hex values for the words are exactly the same as those that appear in the payload issued over the serial line, as printed out by the AT driver. The output size of the string is 84, 160 and 40 bits for the uncompressed, Huffman compressed and LD-based compressed algorithms respectively.

Consistent with our earlier observation, Huffman actually increases the size of a very short string. The increase in size is quite severe, as the Huffman output is almost twice the size of the original message. Alternatively, the LD-based output is almost half the size of the uncompressed message. It is significant to observe that the output produced by the LD-based algorithm is four times as effective as Huffman encoding, which is the official GSM method for compressing SMS messages. The summary shows entries for both "Bits" and "Transmission Bits". The "Bits" entry, which we have already discussed, indicates the size of the compression output. Remember, however, that the payload must be packed into a PDU-SUBMIT PDU. This PDU has a strict structure and requires setting additional header and indicator flags, and it represents the actual size of the SMS message in terms of the number of bits that would be used to carry the SMS message over the GSM network. The difference between the "Bits" and "Transmission Bits" values for each of the three cases is about 10 bits. This difference of 10 bits is constant and there is nothing we can do to optimise it since it forms part of the fixed structure of the PDU. However, since it is a fixed amount that is added to each of the "Bits" values, it should be clear that the case with the highest "Bits" value is also the case with the highest "Transmission Bits" value.

Ref# 0043	
Message	The quick brown fox jumps over the lazy dog
Decompressed message	the quick brown fox jumps over the lazy dog
Characters	43
Hit ratio	100%
Words not found in dictionary	NA - All words found in dictionary

Result	**Uncompressed**	**Huffman**	**LD-based**
Bits	301	400	128
Bits per input char	7.00	9.30	2.98
Transmission bits	424	520	256
Transmission bits per input char	9.86	12.09	5.95
Number of SMS messages	1	1	1
Characters per SMS	43.00	43.00	43.00

Table 5.8: Results of encoding and sending SMS message Ref# 0043

The results for Ref#0043 (shown in Table 5.8) are similar to those of the previous message and the hit ratio is again 100%. The message "The quick brown fox jumps over the lazy dog" is an interesting one in that it uses every letter in the alphabet. Using the entire alphabet in such a short message means that there is little repetition for Huffman encoding to exploit. Remember that Huffman encoding attempts to find those patterns that occur most often in an input stream and then replaces each of these patterns with the shortest possible keyword. The most frequently occurring patterns are assigned the shortest codewords, and the least frequently occurring ones are assigned the longest codewords. Once again, Huffman encoding increased the size of the message, while LD-based encoding decreased it by more than half. However, since the message in all cases can be transmitted as a single SMS message, there are no cost savings in this case. The actual size of an SMS message matters little as long as that size is less than the maximum length of a single SMS message. In all these cases, all the characters were accommodated in a single SMS message, meaning a consistent 43 characters.

Ref# 0064	
Message	Now is the time for all good men to come to the aid of the party
Decompressed message	now is the time for all good men to come to the aid of the party
Characters	64
Hit ratio	100%
Words not found in dictionary	NA - All words found in dictionary

Result	**Uncompressed**	**Huffman**	**LD-based**
Bits	448	504	176
Bits per input char	7.00	7.88	2.75
Transmission bits	568	624	304
Transmission bits per input char	8.88	9.75	4.75
Number of SMS messages	1	1	1
Characters per SMS	64.00	64.00	64.00

Table 5.9: Results of encoding and sending SMS message Ref# 0064

Looking at the results from Table 5.9, a pattern starts to emerge; for each of the previous three messages, the Huffman algorithm increased the number of bits when compared to the uncompressed message, while the LD-based algorithm reduced the size. The reduction this time is quite drastic; the LD-based output is 60% smaller than that of the uncompressed message. We expect Huffman encoding to clearly demonstrate its advantages as messages become longer, surpassing the LD-based algorithm.

Ref# 0179	
Message	Thanks! Hope you have great Xmas too! What you up to these days? Still in London? Can't believe I've been back in NZ for nearly 18 months, but I'm still loving every minute of it!
Decompressed message	thanks! hope you have great xmas too! what you up to these days? still in london? can't believe i've been back in nz for nearly 18 months, but i'm still loving every minute of it!
Characters	179
Hit ratio	91%
Words not found in dictionary	18, nz, xmas

Result	**Uncompressed**	**Huffman**	**LD-based**
Bits	1253	1184	592
Bits per input char	7.00	6.61	3.31
Transmission bits	1592	1520	720
Transmission bits per input char	8.89	8.49	4.02
Number of SMS messages	2	2	1
Characters per SMS	89.50	89.50	179.00

Table 5.10: Results of encoding and sending SMS message Ref# 0179

Ref#0179 (results in Table 5.10) is the first string tested that is longer than the 160-character limit. In addition, in this example not all of the words can be found in the dictionary; the hit ratio stood at 91% with words like "18", "nz" or "xmas" left unresolved. For each of these words, the LD-based algorithm relied on per-character encoding. Notice how, for instance, "xmas" was encoded as "x" + "m" + "a" + "s". Despite not finding all of the words in the dictionary, the LD-based compression reduced the total number of SMS messages necessary to send the text from two to one. Note that, as the strings become a little bit longer, Huffman encoding shows some benefit; thus, for the first time, Huffman compression shrinks the size of the message, albeit by a modest amount insufficient to shorten it into a single SMS message.

Ref# 0205	
Message	Yes, but to be honest, when I am working on a problem I never think about beauty. I only think about how to solve the problem. But when I have finished, if the solution is not beautiful, I know it is wrong
Decompressed message	yes, but to be honest, when i am working on a problem i never think about beauty. i only think about how to solve the problem. but when i have finished, if the solution is not beautiful, i know it is wrong
Characters	205
Hit ratio	100%
Words not found in dictionary	NA - All words found in dictionary

Result	**Uncompressed**	**Huffman**	**LD-based**
Bits	1435	1112	608
Bits per input char	7.00	5.42	2.97
Transmission bits	1776	1232	736
Transmission bits per input char	8.66	6.01	3.59
Number of SMS messages	2	1	1
Characters per SMS	102.50	205.00	205.00

Table 5.11: Results of encoding and sending SMS message Ref# 0205

The experiments were conducted in order of increasing message size. Ref#0205 (results shown in Table 5.11) and those that follow are all more than the 160-character limit for a single SMS message. The trends previously observed continue in that Huffman encoding produces more of a saving, but this saving is still not nearly as much as that resulting from LD-based compression. This time, however, Huffman encoding did reduce the number of SMS text messages to one. This finding emphasises just how much Huffman compression is biased against short strings. In the previous experiment, the character count was smaller than in this case, yet two separate SMS messages were required. Now that the character count has increased, Huffman compression has more text to optimise and thus can reduce the output to a single SMS message. It is not the number of bits that matter directly but rather the number of SMS messages, and so in this case the outcome favours Huffman and LD-based compression equally. Both Huffman and LD-based compression fit 205 characters into a single SMS message, thereby coming under the 160-character limit.

Ref# 0353	
Message	Hey mate, how are you? Meant to email you after a trip to cape town to let you know i'd finally seen your beautiful city. What are you doing in london when you can call cape town home? Was a nice change from life in the slums too. Hopefully coming over for a wedding in April next year - will keep you posted. And would love you to come visit Australia!
Decompressed message	hey mate, how are you? meant to email you after a trip to cape town to let you know i'd finally seen your beautiful city. what are you doing in london when you can call cape town home? was a nice change from life in the slums too. hopefully coming over for a wedding in april next year - will keep you posted. and would love you to come visit australia!
Characters	353
Hit ratio	98%
Words not found in dictionary	slums

Result	**Uncompressed**	**Huffman**	**LD-based**
Bits	2471	1856	1080
Bits per input char	7.00	5.26	3.06
Transmission bits	2984	2192	1208
Transmission bits per input char	8.45	6.21	3.42
Number of SMS messages	3	2	1
Characters per SMS	117.67	176.50	353.00

Table 5.12: Results of encoding and sending SMS message Ref# 0353

Table 5.12 shows the results for test run Ref#0353. In this test, the hit ratio is 98%, because "slums" does not exist in the dictionary. The uncompressed message would be sent in three parts, while the Huffman-compressed version would be sent in two parts. Finally, the LD-based message would still only require a single SMS message to accommodate all 353 characters of the message.

Ref# 0600	
Message	And so it was indeed: she was now only ten inches high, and her face brightened up at the thought that she was now the right size for going through the little door into that lovely garden. First, however, she waited for a few minutes to see if she was going to shrink any further: she felt a little nervous about this; 'for it might end, you know,' said Alice to herself, 'in my going out altogether, like a candle. I wonder what I should be like then?' And she tried to fancy what the flame of a candle is like after the candle is blown out, for she could not remember ever having seen such a thing.
Decompressed message	and so it was indeed: she was now only ten inches high, and her face brightened up at the thought that she was now the right size for going through the little door into that lovely garden. first, however, she waited for a few minutes to see if she was going to shrink any further: she felt a little nervous about this; 'for it might end, you know,' said alice to herself, 'in my going out altogether, like a candle. i wonder what i should be like then?' and she tried to fancy what the flame of a candle is like after the candle is blown out, for she could not remember ever having seen such a thing.
Characters	600
Hit ratio	99%
Words not found in dictionary	brightened

Result	**Uncompressed**	**Huffman**	**LD-based**
Bits	4200	2768	1768
Bits per input char	7.00	4.61	2.95
Transmission bits	4880	3272	2112
Transmission bits per input char	8.13	5.45	3.52
Number of SMS messages	4	3	2
Characters per SMS	150.00	200.00	300.00

Table 5.13: Results of encoding and sending SMS message Ref# 0600

The excerpted text for Ref#0600 (results shown in Table 5.13) was taken from *Alice in Wonderland.* Only "brightened" was not found in the dictionary, bringing the hit ratio to 99%. In all experiments thus far, the dictionary provided adequate coverage, as was the case for the novels, making it possible to achieve a satisfactory compression ratio. The uncompressed, Huffman-compressed and LD-based messages required four, three and two parts respectively. Note that, during transmission, the message was sent as two separate SMS-SUBMIT PDUs. In addition, on delivery there were two unread SMS-DELIVERY PDUs. Significantly, in this case, we have proven that we are able to use LD-based

encoding to send and reassemble multipart SMS messages, just as in standard concatenated SMS. However, instead of the handset reassembling the message, we had to reassemble it ourselves.

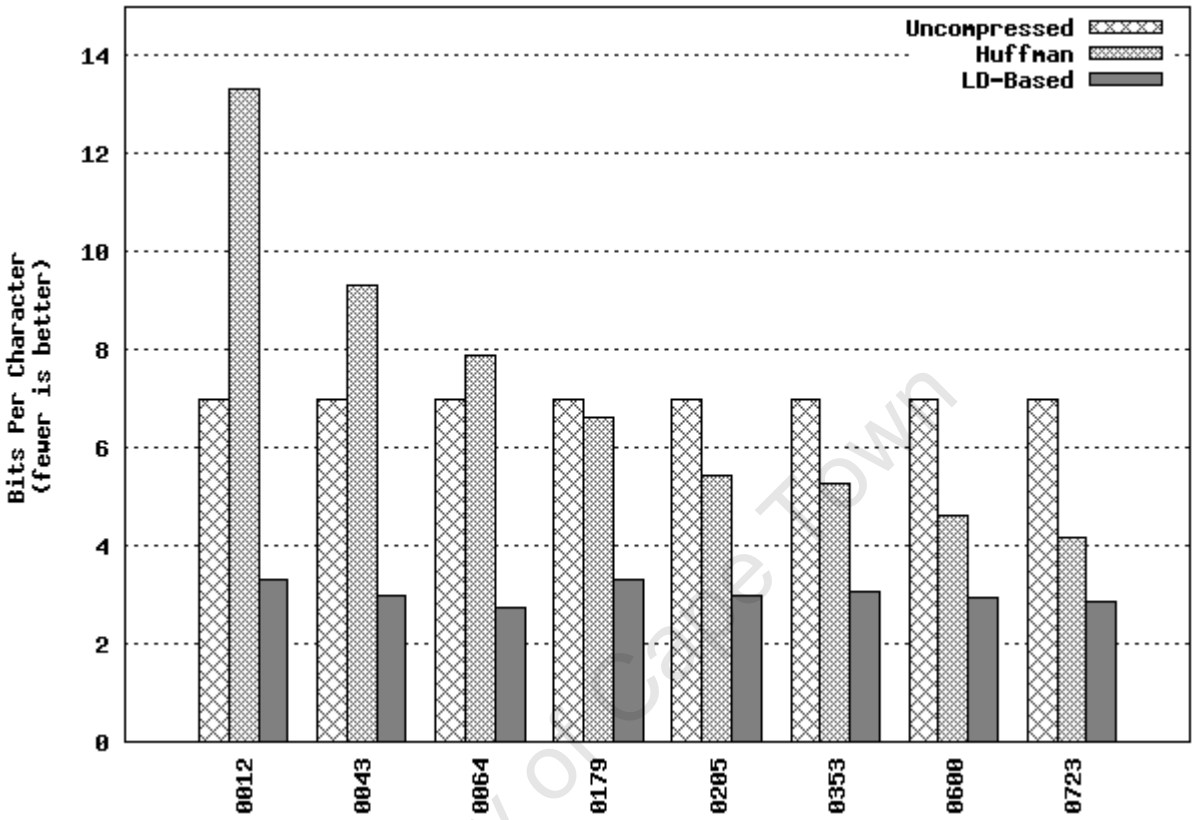
Ref# 0723	
Message	We understand it still that there is no easy road to freedom. We know it well that none of us acting alone can achieve success. We must therefore act together as a united people, for national reconciliation, for nation building, for the birth of a new world. Let there be justice for all. Let there be peace for all. Let there be work, bread, water and salt for all. Let each know that for each the body, the mind and the soul have been freed to fulfill themselves. Never, never and never again shall it be that this beautiful land will again experience the oppression of one by another and suffer the indignity of being the skunk of the world. Let freedom reign. The sun shall never set on so glorious a human achievement!
Decompressed message	we understand it still that there is no easy road to freedom. we know it well that none of us acting alone can achieve success. we must therefore act together as a united people, for national reconciliation, for nation building, for the birth of a new world. let there be justice for all. let there be peace for all. let there be work, bread, water and salt for all. let each know that for each the body, the mind and the soul have been freed to fulfill themselves. never, never and never again shall it be that this beautiful land will again experience the oppression of one by another and suffer the indignity of being the skunk of the world. let freedom reign. the sun shall never set on so glorious a human achievement!
Characters	723
Hit ratio	99%
Words not found in dictionary	indignity

Result	**Uncompressed**	**Huffman**	**LD-based**
Bits	5061	3016	2064
Bits per input char	7.00	4.17	2.85
Transmission bits	5912	3520	2408
Transmission bits per input char	8.18	4.87	3.33
Number of SMS messages	5	3	2
Characters per SMS	144.60	241.00	361.50

Table 5.14: Results of encoding and sending SMS message Ref# 0723

The last message, Ref#0723, is fairly long at 723 characters; messages longer than this would probably be quite scarce. The uncompressed message would require five parts, while the Huffman

algorithm would encode the message into three parts. Finally, the LD-based message would only require two parts, fitting roughly 361 characters into a single SMS message. Next, we take a look at our results across the experiments.

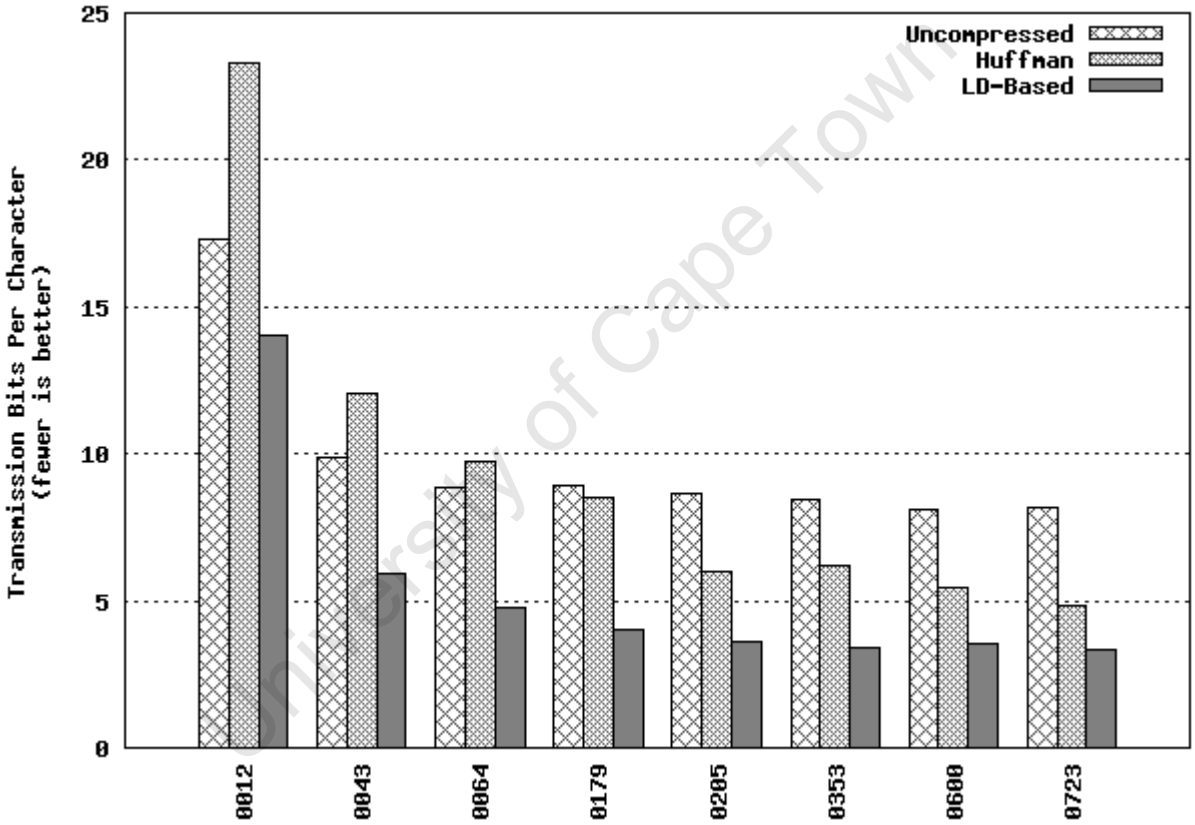


Length	Uncompressed	Huffman	LD-based
0012	7.00	13.33	3.33
0043	7.00	9.30	2.98
0064	7.00	7.88	2.75
0179	7.00	6.61	3.31
0205	7.00	5.42	2.97
0353	7.00	5.26	3.06
0600	7.00	4.61	2.95
0723	7.00	4.17	2.85

Figure 5.1: The average number of bits used to encode each of the characters in the compressed message. The lower the number, the better the compression.

Figure 5.1 shows that the uncompressed message always uses the standard 7 bits per character as encoded per ETSI GSM 03.38 and thus acts only as a baseline. When compressing messages with Huffman encoding, the first four messages, which are the shortest ones, actually result in an increase

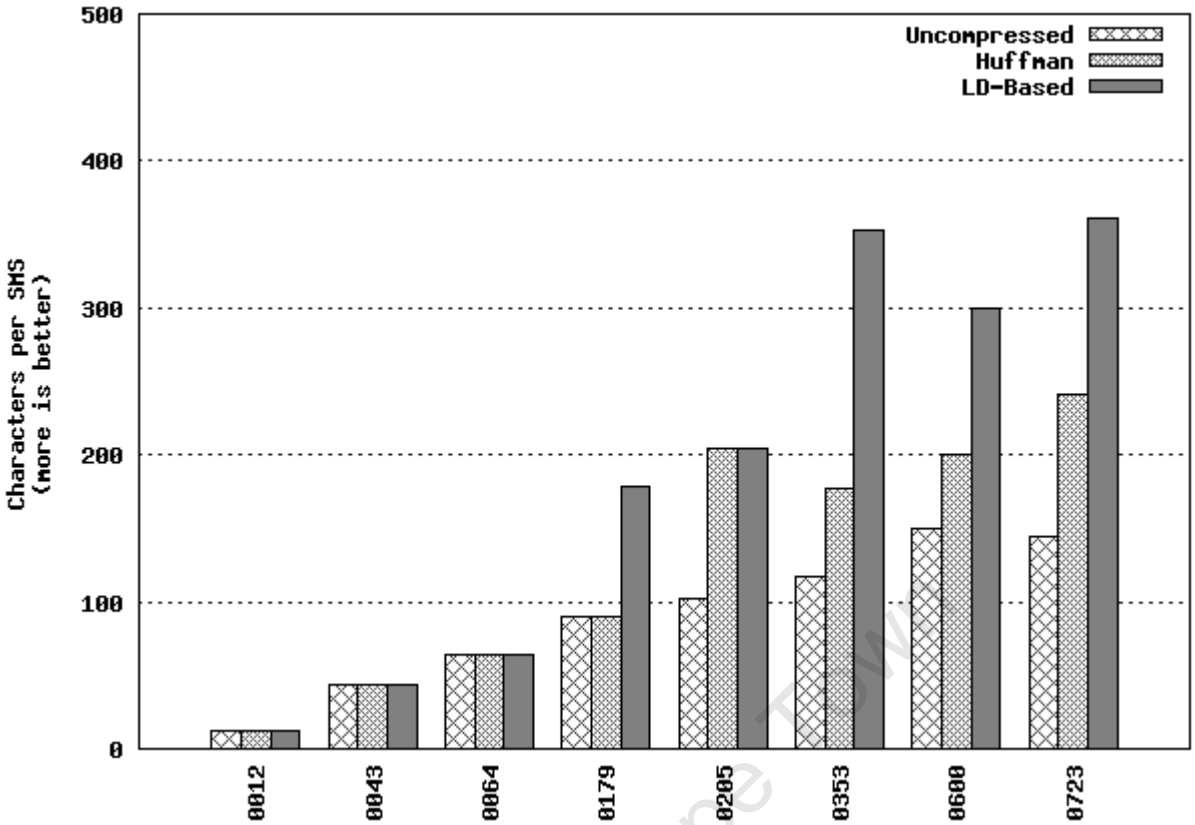
in the number of bits required to capture a character. We see that the Huffman algorithm performs consistently better as the message size increases, and thus we expect this trend to continue as message length becomes longer, beyond that considered in these experiments. This was indeed observed when encoding novels. However, the range of message sizes evaluated is considered representative of the length of messages users would typically type when sending an SMS message. The performance of the LD-based method does not show any improvement for a longer message size, nor does it show a penalty for shorter messages. Huffman encoding is heavily dependent on the size of the messages, as it depends on the opportunity to exploit repeating patterns. In contrast, LD-based encoding shows no such bias – the more words found in the dictionary, the better the result. The encoding shows results consistent in the range of 2.85 to 3.33 bits per character.



Length	Uncompressed	Huffman	LD-based
0012	17.33	23.33	14.00
0043	9.86	12.09	5.95
0064	8.88	9.75	4.75
0179	8.89	8.49	4.02
0205	8.66	6.01	3.59
0353	8.45	6.21	3.42
0600	8.13	5.45	3.52
0723	8.18	4.87	3.33

Figure 5.2: The average number of bits per character used in the PDU. Once the message is encoded with the compression method, it is then passed through a second stage of encoding to package the payload into the PDU transmission format.

Whereas Figure 5.1 shows the bits per character as a result of compressing the message, Figure 5.2 shows the bits per character necessary to transmit the message. The figures are larger as a result of the addition of meta-information required to structure the data into PDU format. It is worth considering this result in that it clearly shows the so-called "effective" bits per character or, put another way, the total bits required to transmit the message against the size of the content. The overhead is consistent in that the same number of bits are added under the uncompressed, Huffman-compressed and LD-based compressed methods within a single experiment. In the first instance, regarding message 0012, the penalty is about 10 bits. The bit count per character for an uncompressed message increases from 7 to 17.33, whereas the count for the Huffman method increases from 13.33 to 23.33. The LD-based count increases from 3.33 to 14.00. The trend continues, but becomes less severe as the message size increases.

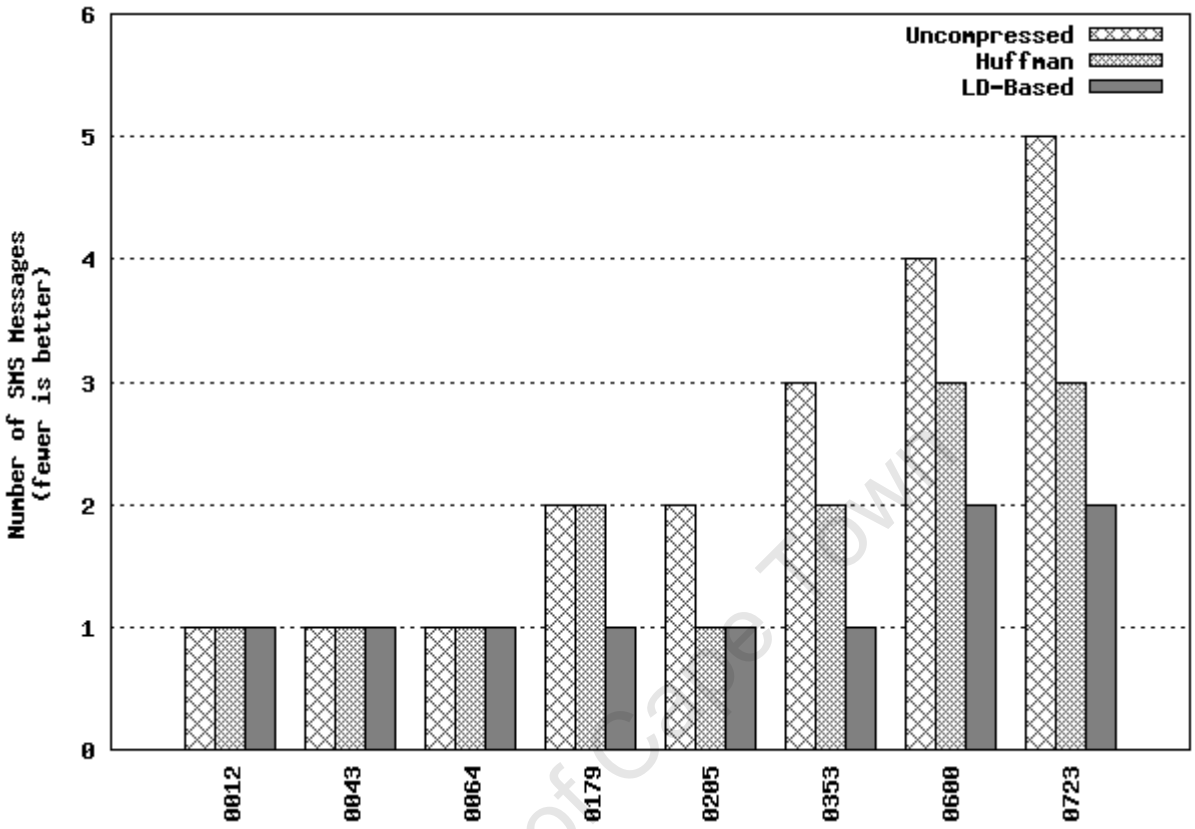


Length	Uncompressed	Huffman	LD-based
0012	12.00	12.00	12.00
0043	43.00	43.00	43.00
0064	64.00	64.00	64.00
0179	89.50	89.50	179.00
0205	102.50	205.00	205.00
0353	117.67	176.50	353.00
0600	150.00	200.00	300.00
0723	144.60	241.00	361.50

Figure 5.3: The number of characters fitted into each SMS part. A standard SMS can accommodate 160 characters and a concatenated SMS can take max 153 characters per part. Using LD-based compression, the maximum was extended to 361 characters.

To use as few parts as possible per message, it is important to fit as many characters as possible in each SMS message. The hard limit is 160 characters for a single SMS message, or 153 characters for every part of a concatenated SMS message (i.e. 1120 bits minus a 6-byte header leaves 1072 bits that can fit 153 7-bit characters). The values in Figure 5.3 are the average taken across all of the parts making up the whole, but, of course, none of the uncompressed messages exceeded the 153-character

limit. With the aid of Huffman encoding, a maximum count of 241 characters was achieved; this figure was 361 with LD-based encoding.



Length	Uncompressed	Huffman	LD-based
0012	1	1	1
0043	1	1	1
0064	1	1	1
0179	2	2	1
0205	2	1	1
0353	3	2	1
0600	4	3	2
0723	5	3	2

Figure 5.4: The number of SMS messages (or concatenated SMS parts) to transmit each of the test messages.

Moving from compressed bits per character to transmission bits per character to characters per SMS message, we finally consider the overall aim of this study, that is, to reduce the number of SMS messages for communicating a given message (shown in Figure 5.4). Neither Huffman nor LD-based encoding left the message count worse off in any of the instances under consideration. There was

either no benefit for some of the cases or a reduction. However, LD-based encoding yielded a better result in all instances. As the formal compression scheme adopted in GSM specification, Huffman encoding did produce savings for longer messages, while LD-based compression yielded even better results.

Chapter 6 - Conclusion

This paper explored the design, implementation and evaluation of a dictionary-based method for compressing English SMS text messages. The dictionary was constructed using frequency lists of those words that appear most often in film scripts and was then tested against some popular novels in English literature. The design is based on lower-case words in order to avoid reserving space for different case permutations (i.e. upper case, mixed case, title case and so on). This decision meant that more unique words could be added to the dictionary, resulting in a greater hit ratio for the input stream and, therefore, greater compression efficiency. The decompressed message thus always appears in lower case, meaning that this decision also leads to a trade-off between efficiency and quality. Therefore, this decompression method becomes a lossy one. The loss of quality in this case only involves the case of the message, and since SMS is largely an informal method of communication, there are situations in which people might be willing to make this trade-off in order to save on their bills. Furthermore, it would be a waste to use 7 bits to encode a space character. Since most words are followed by a space, this is a significant waste of space in that the number of spaces will usually be equal to 1 less than the number of words in the message. The dictionary therefore allows using a single bit to indicate whether or not a word is followed by a space. LD-based dictionary stores more than 16,000 of the most commonly used English words. Nation [38] showed that between 8,000 and 9,000 words are needed for reading and writing and 6,000 to 7,000 words for speaking and listening in order to understand 98% of typical English language. The dictionary setup for instance contains only 45.75% of the unique words in *Origin of the Species*, but can still compress 86.23% of the content. This is because, even though highly specialised in content and vocabulary, the specialised words still do not occur as frequently as the more common words from the dictionary. Table 6.1 gives and overview of how LD-based compression rates against methods discussed in the "Related Work" section.

Algorithm	**Compression ratio in bits per character**
ETSI GSM 03.38	7.00
Huffman	6.01
CleverTexting	5.00
ETSI GSM 03.42	4.67
Nakayama	4.05
Rein, Guehmann and Fitzek	3.29
LD-based	**2.98**

Table 6.1: Comparing the LD-based method against related work.

The GSM specification officially supports Huffman encoding, but we have shown that Huffman encoding is not particularly well-suited to short messages, since the overhead of encoding the dictionary into the data stream adds to the message size, often increasing the size of messages rather than reducing them. The results indicate that the method outperforms Huffman encoding for small messages in the size range expected for SMS texts and that it might offer a better alternative. The major drawback of the proposed compression method is that the dictionary would need to be installed on both the sending and the receiving handsets, thereby using some of the already limited memory on the phone. The dictionary measures 316 Kb in size, which should easily fit on modern handsets, many of which can store MP3 albums and films.

Chapter 7 - Future work

The current version of the compression scheme presented here has been shown to achieve the goal of decreasing the size of text messages, even outperforming the standard GSM method of compression. Further fine-tuning could be performed to improve the results even more. If a word were misspelt, for example, it would not be found in the dictionary and thus would need to be encoded one character at a time. It might make sense to use the dictionary as a spell-checker prior to encoding the message.

The current form of the dictionary stores either characters or words, but further savings could be attained by also storing commonly used phrases. There is no support for encoding hyphenated words, and so something like “devil-may-care” would not yield a hit from the dictionary. The algorithm could be improved by splitting up such words at the point of the hyphen and storing the result as “[devil][-][may][-][care]”. This improvement could be made even more generic in order to scan any words not found in the dictionary to see whether they could be split into parts that do exist in the dictionary. Something like “easement ” could then be encoded as “[ease][m][e][n][t]”.

Further revisions to the dictionary would require the inclusion of a scheme by which to indicate the appropriate version of the dictionary to use when decompressing the message. This could be achieved by including dictionary version information in the compression header. Dictionaries could also be created for other languages, as there is nothing inherent in the algorithm that prevents support for other languages. That is, language-specific dictionaries could be created and then indicated in the compression header.

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Appendix A - Printout Ref# 0012

```
Details
=========================================
GSM Modem SerialPort: /dev/ttyUSB0
PhoneNumber: 07894555501
Message: Hello World!

Starting...

Stable Library
=========================================
Native lib Version = RXTX-2.1-7
Java lib Version   = RXTX-2.1-7
Tx: ATE0
Rx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CMGS=20
Rx: >
Tx: 0011000B817098545505F100F4FF0600814BC14702#
Rx: +CMGS: 56
Rx: OK

Sending done!

Waiting 60 seconds before trying to read message. This gives it time to be delivered from the
GSM network...
OK, here we go.

Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CPMS?
Rx: +CPMS: "ME",1,25,"SM",0,50,"SM",0,50
Rx: OK
Tx: AT+CMGR=1
Rx: +CMGR: 0,,25
Rx: 079144872000302304 0C9144874955551000F490019281051200 0600814BC14702
Rx: OK

Found Unread Message: 079144872000302304 0C9144874955551000F490019281051200 0600814BC14702

Delete all messages in store as part of housekeeping

Tx: AT+CMGD=1
Rx: OK
Deleted message at index 1

Decompressed Message: hello world!

Receiving done!

Please wait, generating report...
Report generated.

SMS Compression Report
=============================================
```

REF# 0012

Text Message [12 characters]: Hello World!

Words Not Found in Dictionary [100.00 percent hit ratio]
==========
[N/A - All words exist in dictonary]

Dictionary Symbol	Dictionay Index	Encoded Hex Byte(s)	Encoded Binary Byte(s)
[compression indicator]	0	00	00000000
hello[sp]	331	814B	10000001 01001011
world	16711	C147	11000001 01000111
!	2	02	00000010

REF# 0012 [12 chars]	Uncompressed	Huffman	LD-Based
Bits:	84	160	40
Bits Per Input Char:	7.00	13.33	3.33
Transmission Bits:	208	280	168
Transmission Bits Per Input Char:	17.33	23.33	14.00
Number of SMS Messages:	1	1	1
Characters per SMS:	12.00	12.00	12.00

Experimental: JNI_OnLoad called.

Appendix B - Printout Ref# 0043

```
Details
========================================
GSM Modem SerialPort: /dev/ttyUSB0
PhoneNumber: 07894555501
Message: The quick brown fox jumps over the lazy dog

Starting...

Stable Library
========================================
Native lib Version = RXTX-2.1-7
Java lib Version   = RXTX-2.1-7
Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CMGS=31
Rx: >
Tx: 0011000B817098545505F100F4FF110048842E86DC8E8B9BE780B9489612C316#
Rx: +CMGS: 57
Rx: OK

Sending done!

Waiting 60 seconds before trying to read message. This gives it time to be delivered from the
GSM network...
OK, here we go.

Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CPMS?
Rx: +CPMS: "ME",1,25,"SM",0,50,"SM",0,50
Rx: OK
Tx: AT+CMGR=1
Rx: +CMGR: 0,,36
Rx: 07914487200030230 40C9144874955551000F490019281158300110048842E86DC8E8B9BE780B9489612C316
Rx: OK

Found Unread Message:
07914487200030230 40C9144874955551000F490019281158300110048842E86DC8E8B9BE780B9489612C316

Delete all messages in store as part of housekeeping

Tx: AT+CMGD=1
Rx: OK
Deleted message at index 1

Decompressed Message: the quick brown fox jumps over the lazy dog

Receiving done!

Please wait, generating report...
Report generated.

SMS Compression Report
================================================
```

REF# 0043

Text Message [43 characters]: The quick brown fox jumps over the lazy dog

Words Not Found in Dictionary [100.00 percent hit ratio]
==========
[N/A - All words exist in dictonary]

Dictionary Symbol	Dictionay Index	Encoded Hex Byte(s)	Encoded Binary Byte(s)
[compression indicator]	0	00	00000000
the[sp]	72	48	01001000
quick[sp]	1070	842E	10000100 00101110
brown[sp]	1756	86DC	10000110 11011100
fox[sp]	3723	8E8B	10001110 10001011
jumps[sp]	7143	9BE7	10011011 11100111
over[sp]	185	80B9	10000000 10111001
the[sp]	72	48	01001000
lazy[sp]	5650	9612	10010110 00010010
dog	17174	C316	11000011 00010110

REF# 0043 [43 chars]	Uncompressed	Huffman	LD-Based
Bits:	301	400	128
Bits Per Input Char:	7.00	9.30	2.98
Transmission Bits:	424	520	256
Transmission Bits Per Input Char:	9.86	12.09	5.95
Number of SMS Messages:	1	1	1
Characters per SMS:	43.00	43.00	43.00

Experimental: JNI_OnLoad called.

Appendix C - Printout Ref# 0064

```
Details
========================================
GSM Modem SerialPort: /dev/ttyUSB0
PhoneNumber: 07894555501
Message: Now is the time for all good men to come to the aid of the party

Starting...

Stable Library
========================================
Native lib Version = RXTX-2.1-7
Java lib Version   = RXTX-2.1-7
Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CMGS=37
Rx: >
Tx: 0011000B817098545505F100F4FF17007B4F48808E54658087823E47808647488F7E4C48C1C2#
Rx: +CMGS: 58
Rx: OK

Sending done!

Waiting 60 seconds before trying to read message. This gives it time to be delivered from the
GSM network...
OK, here we go.

Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CPMS?
Rx: +CPMS: "ME",1,25,"SM",0,50,"SM",0,50
Rx: OK
Tx: AT+CMGR=1
Rx: +CMGR: 0,,42
Rx:
07914487200030230 40C9144874955551000F490019281255500170 07B4F48808E54658087823E47808647488F7E4
C48C1C2
Rx: OK

Found Unread Message:
07914487200030230 40C9144874955551000F490019281255500170 07B4F48808E54658087823E47808647488F7E4
C48C1C2

Delete all messages in store as part of housekeeping

Tx: AT+CMGD=1
Rx: OK
Deleted message at index 1

Decompressed Message: now is the time for all good men to come to the aid of the party

Receiving done!

Please wait, generating report...
Report generated.
```

SMS Compression Report
==========

REF# 0064

Text Message [64 characters]: Now is the time for all good men to come to the aid of the party

Words Not Found in Dictionary [100.00 percent hit ratio]
==========
[N/A - All words exist in dictonary]

Dictionary Symbol	Dictionay Index	Encoded Hex Byte(s)	Encoded Binary Byte(s)
[compression indicator]	0	00	00000000
now[sp]	123	7B	01111011
is[sp]	79	4F	01001111
the[sp]	72	48	01001000
time[sp]	142	808E	10000000 10001110
for[sp]	84	54	01010100
all[sp]	101	65	01100101
good[sp]	135	8087	10000000 10000111
men[sp]	574	823E	10000010 00111110
to[sp]	71	47	01000111
come[sp]	134	8086	10000000 10000110
to[sp]	71	47	01000111
the[sp]	72	48	01001000
aid[sp]	3966	8F7E	10001111 01111110
of[sp]	76	4C	01001100
the[sp]	72	48	01001000
party	16834	C1C2	11000001 11000010

REF# 0064 [64 chars]	Uncompressed	Huffman	LD-Based
Bits:	448	504	176
Bits Per Input Char:	7.00	7.88	2.75
Transmission Bits:	568	624	304
Transmission Bits Per Input Char:	8.88	9.75	4.75
Number of SMS Messages:	1	1	1
Characters per SMS:	64.00	64.00	64.00

Experimental: JNI_OnLoad called.

Appendix D - Printout Ref# 0179

```
Details
=========================================
GSM Modem SerialPort: /dev/ttyUSB0
PhoneNumber: 07894555501
Message: Thanks! Hope you have great Xmas too! What you up to these days? Still in London?
Can't believe I've been back in NZ for nearly 18 months, but I'm still loving every minute of
it!

Starting...

Stable Library
=========================================
Native lib Version = RXTX-2.1-7
Java lib Version   = RXTX-2.1-7
Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CMGS=89
Rx: >
Tx:
0011000B817098545505F100F4FF4B00C0EB02018155465680E73F34283A01C08E02014E46774780F9C1CF200180D
C50C9A42001809280EF80B5809E8091503541015488551219O1C27F0D01645380DC85C2813581694CC02702#
Rx: +CMGS: 59
Rx: OK

Sending done!

Waiting 60 seconds before trying to read message. This gives it time to be delivered from the
GSM network...
OK, here we go.

Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CPMS?
Rx: +CPMS: "ME",1,25,"SM",0,50,"SM",0,50
Rx: OK
Tx: AT+CMGR=1
Rx: +CMGR: 0,,94
Rx:
07914487200030230 40C9144874955551000F4900192814531004B00C0EB02018155465680E73F34283A01C08E020
14E46774780F9C1CF200180DC50C9A42001809280EF80B5809E8091503541015488551219O1C27F0D01645380DC85
C2813581694CC02702
Rx: OK

Found Unread Message:
07914487200030230 40C9144874955551000F4900192814531004B00C0EB02018155465680E73F34283A01C08E020
14E46774780F9C1CF200180DC50C9A42001809280EF80B5809E8091503541015488551219O1C27F0D01645380DC85
C2813581694CC02702

Delete all messages in store as part of housekeeping

Tx: AT+CMGD=1
Rx: OK
Deleted message at index 1

Decompressed Message: thanks! hope you have great xmas too! what you up to these days? still
```

in london? can't believe i've been back in nz for nearly 18 months, but i'm still loving every minute of it!

Receiving done!

Please wait, generating report...
Report generated.

SMS Compression Report
==========

REF# 0179

Text Message [179 characters]: Thanks! Hope you have great Xmas too! What you up to these days? Still in London? Can't believe I've been back in NZ for nearly 18 months, but I'm still loving every minute of it!

Words Not Found in Dictionary [91.00 percent hit ratio]
==========
18
nz
xmas

Dictionary Symbol	Dictionay Index	Encoded Hex Byte(s)	Encoded Binary Byte(s)
[compression indicator]	0	00	00000000
thanks	16619	C0EB	11000000 11101011
!	2	02	00000010
[sp]	1	01	00000001
hope[sp]	341	8155	10000001 01010101
you[sp]	70	46	01000110
have[sp]	86	56	01010110
great[sp]	231	80E7	10000000 11100111
x	63	3F	00111111
m	52	34	00110100
a	40	28	00101000
s	58	3A	00111010
[sp]	1	01	00000001
too	16526	C08E	11000000 10001110
!	2	02	00000010
[sp]	1	01	00000001
what[sp]	78	4E	01001110
you[sp]	70	46	01000110
up[sp]	119	77	01110111
to[sp]	71	47	01000111
these[sp]	249	80F9	10000000 11111001
days	16847	C1CF	11000001 11001111
?	32	20	00100000
[sp]	1	01	00000001
still[sp]	220	80DC	10000000 11011100
in[sp]	80	50	01010000
london	18852	C9A4	11001001 10100100
?	32	20	00100000
[sp]	1	01	00000001
can't[sp]	146	8092	10000000 10010010
believe[sp]	239	80EF	10000000 11101111
i've[sp]	181	80B5	10000000 10110101
been[sp]	158	809E	10000000 10011110
back[sp]	145	8091	10000000 10010001
in[sp]	80	50	01010000
n	53	35	00110101
z	65	41	01000001
[sp]	1	01	00000001
for[sp]	84	54	01010100
nearly[sp]	2133	8855	10001000 01010101
1	18	12	00010010
8	25	19	00011001
[sp]	1	01	00000001
months	17023	C27F	11000010 01111111
,	13	0D	00001101
[sp]	1	01	00000001
but[sp]	100	64	01100100
i'm[sp]	83	53	01010011
still[sp]	220	80DC	10000000 11011100
loving[sp]	1474	85C2	10000101 11000010
every[sp]	309	8135	10000001 00110101
minute[sp]	361	8169	10000001 01101001
of[sp]	76	4C	01001100
it	16423	C027	11000000 00100111

```
!                                    2                  02              00000010

REF# 0179 [179 chars]              Uncompressed  Huffman  LD-Based
=========================================================================
Bits:                                   1253     1184       592
Bits Per Input Char:                    7.00     6.61      3.31
Transmission Bits:                      1592     1520       720
Transmission Bits Per Input Char:       8.89     8.49      4.02
Number of SMS Messages:                    2        2         1
Characters per SMS:                    89.50    89.50    179.00


Experimental:  JNI_OnLoad called.
```

Appendix E - Printout Ref# 0205

```
Details
========================================
GSM Modem SerialPort: /dev/ttyUSB0
PhoneNumber: 07894555501
Message: Yes, but to be honest, when I am working on a problem I never think about beauty. I
only think about how to solve the problem. But when I have finished, if the solution is not
beautiful, I know it is wrong

Starting...

Stable Library
========================================
Native lib Version = RXTX-2.1-7
Java lib Version   = RXTX-2.1-7
Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CMGS=91
Rx: >
Tx:
0011000B817098545505F100F4FF4D00C0780D0164475CC3270D01808D300180C081D85D280181683001 80B0796AC
79D0F01300180D5796A7F478A3448C1440F0164808D300156C3C70D0173488B1A4F5AC1BE0D013001524B4FC0EF#
Rx: +CMGS: 60
Rx: OK

Sending done!

Waiting 60 seconds before trying to read message. This gives it time to be delivered from the
GSM network...
OK, here we go.

Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CPMS?
Rx: +CPMS: "ME",1,25,"SM",0,50,"SM",0,50
Rx: OK
Tx: AT+CMGR=1
Rx: +CMGR: 0,,96
Rx:
0791448720003023040C9144874955551000F4900192815503004D00C0780D0164475CC3270D01808D300180C081D
85D28018168300180B0796AC79D0F01300180D5796A7F478A3448C1440F0164808D300156C3C70D0173488B1A4F5A
C1BE0D013001524B4FC0EF
Rx: OK

Found Unread Message:
0791448720003023040C9144874955551000F4900192815503004D00C0780D0164475CC3270D01808D300180C081D
85D28018168300180B0796AC79D0F01300180D5796A7F478A3448C1440F0164808D300156C3C70D0173488B1A4F5A
C1BE0D013001524B4FC0EF

Delete all messages in store as part of housekeeping

Tx: AT+CMGD=1
Rx: OK
Deleted message at index 1

Decompressed Message: yes, but to be honest, when i am working on a problem i never think
```

about beauty. i only think about how to solve the problem. but when i have finished, if the solution is not beautiful, i know it is wrong

Receiving done!

Please wait, generating report...
Report generated.

SMS Compression Report
==========

REF# 0205

Text Message [205 characters]: Yes, but to be honest, when I am working on a problem I never think about beauty. I only think about how to solve the problem. But when I have finished, if the solution is not beautiful, I know it is wrong

Words Not Found in Dictionary [100.00 percent hit ratio]
==========
[N/A - All words exist in dictonary]

Dictionary Symbol	Dictionay Index	Encoded Hex Byte(s)	Encoded Binary Byte(s)
[compression indicator]	0	00	00000000
yes	16504	C078	11000000 01111000
,	13	0D	00001101
[sp]	1	01	00000001
but[sp]	100	64	01100100
to[sp]	71	47	01000111
be[sp]	92	5C	01011100
honest	17191	C327	11000011 00100111
,	13	0D	00001101
[sp]	1	01	00000001
when[sp]	141	808D	10000000 10001101
i	48	30	00110000
[sp]	1	01	00000001
am[sp]	192	80C0	10000000 11000000
working[sp]	472	81D8	10000001 11011000
on[sp]	93	5D	01011101
a	40	28	00101000
[sp]	1	01	00000001
problem[sp]	360	8168	10000001 01101000
i	48	30	00110000
[sp]	1	01	00000001
never[sp]	176	80B0	10000000 10110000
think[sp]	121	79	01111001
about[sp]	106	6A	01101010
beauty	18333	C79D	11000111 10011101
.	15	0F	00001111
[sp]	1	01	00000001
i	48	30	00110000
[sp]	1	01	00000001
only[sp]	213	80D5	10000000 11010101
think[sp]	121	79	01111001
about[sp]	106	6A	01101010
how[sp]	127	7F	01111111
to[sp]	71	47	01000111
solve[sp]	2612	8A34	10001010 00110100
the[sp]	72	48	01001000
problem	16708	C144	11000001 01000100
.	15	0F	00001111
[sp]	1	01	00000001
but[sp]	100	64	01100100
when[sp]	141	808D	10000000 10001101
i	48	30	00110000
[sp]	1	01	00000001
have[sp]	86	56	01010110
finished	17351	C3C7	11000011 11000111
,	13	0D	00001101
[sp]	1	01	00000001
if[sp]	115	73	01110011
the[sp]	72	48	01001000
solution[sp]	2842	8B1A	10001011 00011010
is[sp]	79	4F	01001111
not[sp]	90	5A	01011010
beautiful	16830	C1BE	11000001 10111110
,	13	0D	00001101
[sp]	1	01	00000001
i	48	30	00110000

```
[sp]                                    1                  01                00000001
know[sp]                               82                  52                01010010
it[sp]                                 75                  4B                01001011
is[sp]                                 79                  4F                01001111
wrong                               16623                C0EF       11000000 11101111

REF# 0205 [205 chars]              Uncompressed  Huffman  LD-Based
=================================================================
Bits:                                  1435     1112       608
Bits Per Input Char:                   7.00     5.42      2.97
Transmission Bits:                     1776     1232       736
Transmission Bits Per Input Char:      8.66     6.01      3.59
Number of SMS Messages:                   2        1         1
Characters per SMS:                  102.50   205.00    205.00


Experimental:  JNI_OnLoad called.
```

Appendix F - Printout Ref# 0353

```
Details
=========================================
GSM Modem SerialPort: /dev/ttyUSB0
PhoneNumber: 07894555501
Message: Hey mate, how are you? Meant to email you after a trip to cape town to let you know
i'd finally seen your beautiful city. What are you doing in london when you can call cape
town home? Was a nice change from life in the slums too. Hopefully coming over for a wedding
in April next year - will keep you posted. And would love you to come visit Australia!

Starting...

Stable Library
=========================================
Native lib Version = RXTX-2.1-7
Java lib Version   = RXTX-2.1-7
Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CMGS=150
Rx: >
Tx:
0011000B817098545505F100F4FF88008097CA150D017F67C0222001828C47B09F4680F72801835A4798D081D5478
0BE46528101826881905E81E2C2DD0F014E674680D25089C8808D467680E598D081D5C0D220015F2801812B81CF80
9680CE50483A333C343A01C08E0F018A35814780B954280182195095008165 81D90E01808F80FB46D3040F0149808
B80B34647808684C1D5F602#
Rx: +CMGS: 61
Rx: OK

Sending done!

Waiting 60 seconds before trying to read message. This gives it time to be delivered from the
GSM network...
OK, here we go.

Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CPMS?
Rx: +CPMS: "ME",1,25,"SM",0,50,"SM",0,50
Rx: OK
Tx: AT+CMGR=1
Rx: +CMGR: 0,,155
Rx:
07914487200030230 40C9144874955551000F490019281659400880080 97CA150D017F67C0222001828C47B09F468
0F72801835A4798D081D54780BE46528101826881905E81E2C2DD0F014E674680D25089C8808D467680E598D081D5
C0D220015F2801812B81CF809680CE50483A333C343A01C08E0F018A35814780B954280182195095008165 81D90E0
1808F80FB46D3040F0149808B80B34647808684C1D5F602
Rx: OK

Found Unread Message:
07914487200030230 40C9144874955551000F490019281659400880080 97CA150D017F67C0222001828C47B09F468
0F72801835A4798D081D54780BE46528101826881905E81E2C2DD0F014E674680D25089C8808D467680E598D081D5
C0D220015F2801812B81CF809680CE50483A333C343A01C08E0F018A35814780B954280182195095008165 81D90E0
1808F80FB46D3040F0149808B80B34647808684C1D5F602

Delete all messages in store as part of housekeeping
```

```
Tx: AT+CMGD=1
Rx: OK
Deleted message at index 1

Decompressed Message: hey mate, how are you? meant to email you after a trip to cape town to
let you know i'd finally seen your beautiful city. what are you doing in london when you can
call cape town home? was a nice change from life in the slums too. hopefully coming over for
a wedding in april next year - will keep you posted. and would love you to come visit
australia!

Receiving done!

Please wait, generating report...
Report generated.

SMS Compression Report
==============================================

REF# 0353

Text Message [353 characters]: Hey mate, how are you? Meant to email you after a trip to cape
town to let you know i'd finally seen your beautiful city. What are you doing in london when
you can call cape town home? Was a nice change from life in the slums too. Hopefully coming
over for a wedding in April next year - will keep you posted. And would love you to come
visit Australia!

Words Not Found in Dictionary [98.00 percent hit ratio]
=======================================================
slums
```

Dictionary Symbol	Dictionay Index	Encoded Hex Byte(s)	Encoded Binary Byte(s)
[compression indicator]	0	00	00000000
hey[sp]	151	8097	10000000 10010111
mate	18965	CA15	11001010 00010101
,	13	0D	00001101
[sp]	1	01	00000001
how[sp]	127	7F	01111111
are[sp]	103	67	01100111
you	16418	C022	11000000 00100010
?	32	20	00100000
[sp]	1	01	00000001
meant[sp]	652	828C	10000010 10001100
to[sp]	71	47	01000111
email[sp]	12447	B09F	10110000 10011111
you[sp]	70	46	01000110
after[sp]	247	80F7	10000000 11110111
a	40	28	00101000
[sp]	1	01	00000001
trip[sp]	858	835A	10000011 01011010
to[sp]	71	47	01000111
cape[sp]	6352	98D0	10011000 11010000
town[sp]	469	81D5	10000001 11010101
to[sp]	71	47	01000111
let[sp]	190	80BE	10000000 10111110
you[sp]	70	46	01000110
know[sp]	82	52	01010010
i'd[sp]	257	8101	10000001 00000001
finally[sp]	616	8268	10000010 01101000
seen[sp]	400	8190	10000001 10010000
your[sp]	94	5E	01011110
beautiful[sp]	482	81E2	10000001 11100010
city	17117	C2DD	11000010 11011101
.	15	0F	00001111
[sp]	1	01	00000001
what[sp]	78	4E	01001110
are[sp]	103	67	01100111
you[sp]	70	46	01000110
doing[sp]	210	80D2	10000000 11010010
in[sp]	80	50	01010000
london[sp]	2504	89C8	10001001 11001000
when[sp]	141	808D	10000000 10001101
you[sp]	70	46	01000110
can[sp]	118	76	01110110
call[sp]	229	80E5	10000000 11100101
cape[sp]	6352	98D0	10011000 11010000
town[sp]	469	81D5	10000001 11010101
home	16594	C0D2	11000000 11010010
?	32	20	00100000

[sp]	1	01	00000001
was[sp]	95	5F	01011111
a	40	28	00101000
[sp]	1	01	00000001
nice[sp]	299	812B	10000001 00101011
change[sp]	463	81CF	10000001 11001111
from[sp]	150	8096	10000000 10010110
life[sp]	206	80CE	10000000 11001110
in[sp]	80	50	01010000
the[sp]	72	48	01001000
s	58	3A	00111010
l	51	33	00110011
u	60	3C	00111100
m	52	34	00110100
s	58	3A	00111010
[sp]	1	01	00000001
too	16526	C08E	11000000 10001110
.	15	0F	00001111
[sp]	1	01	00000001
hopefully[sp]	2613	8A35	10001010 00110101
coming[sp]	327	8147	10000001 01000111
over[sp]	185	80B9	10000000 10111001
for[sp]	84	54	01010100
a	40	28	00101000
[sp]	1	01	00000001
wedding[sp]	537	8219	10000010 00011001
in[sp]	80	50	01010000
april[sp]	5376	9500	10010101 00000000
next[sp]	357	8165	10000001 01100101
year[sp]	473	81D9	10000001 11011001
-	14	0E	00001110
[sp]	1	01	00000001
will[sp]	143	808F	10000000 10001111
keep[sp]	251	80FB	10000000 11111011
you[sp]	70	46	01000110
posted	21252	D304	11010011 00000100
.	15	0F	00001111
[sp]	1	01	00000001
and[sp]	73	49	01001001
would[sp]	139	808B	10000000 10001011
love[sp]	179	80B3	10000000 10110011
you[sp]	70	46	01000110
to[sp]	71	47	01000111
come[sp]	134	8086	10000000 10000110
visit[sp]	1217	84C1	10000100 11000001
australia	22006	D5F6	11010101 11110110
!	2	02	00000010

REF# 0353 [353 chars]	Uncompressed	Huffman	LD-Based
Bits:	2471	1856	1080
Bits Per Input Char:	7.00	5.26	3.06
Transmission Bits:	2984	2192	1208
Transmission Bits Per Input Char:	8.45	6.21	3.42
Number of SMS Messages:	3	2	1
Characters per SMS:	117.67	176.50	353.00

Experimental: JNI_OnLoad called.

Appendix G - Printout Ref# 0600

```
Details
========================================
GSM Modem SerialPort: /dev/ttyUSB0
PhoneNumber: 07894555501
Message: And so it was indeed: she was now only ten inches high, and her face brightened up
at the thought that she was now the right size for going through the little door into that
lovely garden. First, however, she waited for a few minutes to see if she was going to shrink
any further: she felt a little nervous about this; 'for it might end, you know,' said Alice
to herself, 'in my going out altogether, like a candle. I wonder what I should be like then?'
And she tried to fancy what the flame of a candle is like after the candle is blown out, for
she could not remember ever having seen such a thing.

Starting...

Stable Library
========================================
Native lib Version = RXTX-2.1-7
Java lib Version   = RXTX-2.1-7
Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CMGS=154
Rx: >
Tx:
0051000B817098545505F100F4FF8C0500037302010049634B5FC87C1B01755F7B80D5829E9565C2300D01497481A
32939302E2F3B2C352C2B01777E4880D64A755F7B486B8748547081144880AC820480DE4A8431CB200F01C0CA0D01
C72A0D01758861542801 81AB81F547808573755F70478BE580CDC68E1B01758281280180AC84976AC02D1C0108544
B8133C1AC0D0146C02E0D080180CB8C#
Rx: +CMGS: 62
Rx: OK
Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CMGS=108
Rx: >
Tx:
0051000B817098545505F100F4FF5E0500037302027347C3AA0D01085057706FDA9F0D01712801CD810F01300182E
84E300180C95C71C08120080149758 20B4788C44E4896DD4C28018DA54F7180F7488DA54F8BF3C04B0D015475809A
5A811E80EA8174819081B92801C09B0F#
Rx: +CMGS: 63
Rx: OK

Sending done!

Waiting 60 seconds before trying to read message. This gives it time to be delivered from the
GSM network...
OK, here we go.

Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
```

```
Rx: OK
Tx: AT+CPMS?
Rx: +CPMS: "ME",2,25,"SM",0,50,"SM",0,50
Rx: OK
Tx: AT+CMGR=1
Rx: +CMGR: 0,,159
Rx:
07914487200030234 40C9144874955551000F4900192818570008C05000373020100496 34B5FC87C1B01755F7B80D
5829E9565C2300D01497481A32939302E2F3B2C352C2B01777E4880D64A755F7B486B8748547081144880AC820480
DE4A8431CB200F01C0CA0D01C72A0D0175886154280181AB81F547808573755F70478BE580CDC68E1B01758281280
180AC84976AC02D1C0108544B8133C1AC0D0146C02E0D080180CB8C
Rx: OK

Found Unread Message:
07914487200030234 40C9144874955551000F4900192818570008C05000373020100496 34B5FC87C1B01755F7B80D
5829E9565C2300D01497481A32939302E2F3B2C352C2B01777E4880D64A755F7B486B8748547081144880AC820480
DE4A8431CB200F01C0CA0D01C72A0D0175886154280181AB81F547808573755F70478BE580CDC68E1B01758281280
180AC84976AC02D1C0108544B8133C1AC0D0146C02E0D080180CB8C
Tx: AT+CMGR=2
Rx: +CMGR: 0,,113
Rx:
07914487200030234 40C9144874955551000F4900192818591005E05000373020273 47C3AA0D01085057706FDA9F0
D01712801CD810F01300182E84E300180C95C71C0812008014975820B4788C44E4896DD4C28018DA54F7180F7488D
A54F8BF3C04B0D015475809A5A811E80EA8174819081B92801C09B0F
Rx: OK

Found Unread Message:
07914487200030234 40C9144874955551000F4900192818591005E05000373020273 47C3AA0D01085057706FDA9F0
D01712801CD810F01300182E84E300180C95C71C0812008014975820B4788C44E4896DD4C28018DA54F7180F7488D
A54F8BF3C04B0D015475809A5A811E80EA8174819081B92801C09B0F

Delete all messages in store as part of housekeeping

Tx: AT+CMGD=1
Rx: OK
Deleted message at index 1
Tx: AT+CMGD=2
Rx: OK
Deleted message at index 2

Decompressed Message: and so it was indeed: she was now only ten inches high, and her face
brightened up at the thought that she was now the right size for going through the little
door into that lovely garden. first, however, she waited for a few minutes to see if she was
going to shrink any further: she felt a little nervous about this; 'for it might end, you
know,' said alice to herself, 'in my going out altogether, like a candle. i wonder what i
should be like then?' and she tried to fancy what the flame of a candle is like after the
candle is blown out, for she could not remember ever having seen such a thing.

Receiving done!

Please wait, generating report...
Report generated.

SMS Compression Report
==================================================

REF# 0600

Text Message [600 characters]: And so it was indeed: she was now only ten inches high, and
her face brightened up at the thought that she was now the right size for going through the
little door into that lovely garden. First, however, she waited for a few minutes to see if
she was going to shrink any further: she felt a little nervous about this; 'for it might end,
you know,' said Alice to herself, 'in my going out altogether, like a candle. I wonder what I
should be like then?' And she tried to fancy what the flame of a candle is like after the
candle is blown out, for she could not remember ever having seen such a thing.

Words Not Found in Dictionary [99.00 percent hit ratio]
==========================================================
brightened

Dictionary Symbol        Dictionay Index  Encoded Hex Byte(s)  Encoded Binary Byte(s)
=============================================================================================
[compression indicator]                0                   00               00000000
and[sp]                               73                   49               01001001
so[sp]                                99                   63               01100011
it[sp]                                75                   4B               01001011
was[sp]                               95                   5F               01011111
indeed                             18556                C87C       11001000 01111100
:                                     27                   1B               00011011
```

[sp]	1	01		00000001
she[sp]	117	75		01110101
was[sp]	95	5F		01011111
now[sp]	123	7B		01111011
only[sp]	213	80D5	10000000	11010101
ten[sp]	670	829E	10000010	10011110
inches[sp]	5477	9565	10010101	01100101
high	16944	C230	11000010	00110000
,	13	0D		00001101
[sp]	1	01		00000001
and[sp]	73	49		01001001
her[sp]	116	74		01110100
face[sp]	419	81A3	10000001	10100011
b	41	29		00101001
r	57	39		00111001
i	48	30		00110000
g	46	2E		00101110
h	47	2F		00101111
t	59	3B		00111011
e	44	2C		00101100
n	53	35		00110101
e	44	2C		00101100
d	43	2B		00101011
[sp]	1	01		00000001
up[sp]	119	77		01110111
at[sp]	126	7E		01111110
the[sp]	72	48		01001000
thought[sp]	214	80D6	10000000	11010110
that[sp]	74	4A		01001010
she[sp]	117	75		01110101
was[sp]	95	5F		01011111
now[sp]	123	7B		01111011
the[sp]	72	48		01001000
right[sp]	107	6B		01101011
size[sp]	1864	8748	10000111	01001000
for[sp]	84	54		01010100
going[sp]	112	70		01110000
through[sp]	276	8114	10000001	00010100
the[sp]	72	48		01001000
little[sp]	172	80AC	10000000	10101100
door[sp]	516	8204	10000010	00000100
into[sp]	222	80DE	10000000	11011110
that[sp]	74	4A		01001010
lovely[sp]	1073	8431	10000100	00110001
garden	19232	CB20	11001011	00100000
.	15	0F		00001111
[sp]	1	01		00000001
first	16586	C0CA	11000000	11001010
,	13	0D		00001101
[sp]	1	01		00000001
however	18218	C72A	11000111	00101010
,	13	0D		00001101
[sp]	1	01		00000001
she[sp]	117	75		01110101
waited[sp]	2145	8861	10001000	01100001
for[sp]	84	54		01010100
a	40	28		00101000
[sp]	1	01		00000001
few[sp]	427	81AB	10000001	10101011
minutes[sp]	501	81F5	10000001	11110101
to[sp]	71	47		01000111
see[sp]	133	8085	10000000	10000101
if[sp]	115	73		01110011
she[sp]	117	75		01110101
was[sp]	95	5F		01011111
going[sp]	112	70		01110000
to[sp]	71	47		01000111
shrink[sp]	3045	8BE5	10001011	11100101
any[sp]	205	80CD	10000000	11001101
further	18062	C68E	11000110	10001110
:	27	1B		00011011
[sp]	1	01		00000001
she[sp]	117	75		01110101
felt[sp]	641	8281	10000010	10000001
a	40	28		00101000
[sp]	1	01		00000001
little[sp]	172	80AC	10000000	10101100
nervous[sp]	1175	8497	10000100	10010111
about[sp]	106	6A		01101010

this	16429	C02D	11000000	00101101
;	28	1C		00011100
[sp]	1	01		00000001
'	8	08		00001000
for[sp]	84	54		01010100
it[sp]	75	4B		01001011
might[sp]	307	8133	10000001	00110011
end	16812	C1AC	11000001	10101100
,	13	0D		00001101
[sp]	1	01		00000001
you[sp]	70	46		01000110
know	16430	C02E	11000000	00101110
,	13	0D		00001101
'	8	08		00001000
[sp]	1	01		00000001
said[sp]	203	80CB	10000000	11001011
alice[sp]	3187	8C73	10001100	01110011
to[sp]	71	47		01000111
herself	17322	C3AA	11000011	10101010
,	13	0D		00001101
[sp]	1	01		00000001
'	8	08		00001000
in[sp]	80	50		01010000
my[sp]	87	57		01010111
going[sp]	112	70		01110000
out[sp]	111	6F		01101111
altogether	23199	DA9F	11011010	10011111
,	13	0D		00001101
[sp]	1	01		00000001
like[sp]	113	71		01110001
a	40	28		00101000
[sp]	1	01		00000001
candle	19841	CD81	11001101	10000001
.	15	0F		00001111
[sp]	1	01		00000001
i	48	30		00110000
[sp]	1	01		00000001
wonder[sp]	744	82E8	10000010	11101000
what[sp]	78	4E		01001110
i	48	30		00110000
[sp]	1	01		00000001
should[sp]	201	80C9	10000000	11001001
be[sp]	92	5C		01011100
like[sp]	113	71		01110001
then	16513	C081	11000000	10000001
?	32	20		00100000
'	8	08		00001000
[sp]	1	01		00000001
and[sp]	73	49		01001001
she[sp]	117	75		01110101
tried[sp]	523	820B	10000010	00001011
to[sp]	71	47		01000111
fancy[sp]	2244	88C4	10001000	11000100
what[sp]	78	4E		01001110
the[sp]	72	48		01001000
flame[sp]	5853	96DD	10010110	11011101
of[sp]	76	4C		01001100
a	40	28		00101000
[sp]	1	01		00000001
candle[sp]	3493	8DA5	10001101	10100101
is[sp]	79	4F		01001111
like[sp]	113	71		01110001
after[sp]	247	80F7	10000000	11110111
the[sp]	72	48		01001000
candle[sp]	3493	8DA5	10001101	10100101
is[sp]	79	4F		01001111
blown[sp]	3059	8BF3	10001011	11110011
out	16459	C04B	11000000	01001011
,	13	0D		00001101
[sp]	1	01		00000001
for[sp]	84	54		01010100
she[sp]	117	75		01110101
could[sp]	154	809A	10000000	10011010
not[sp]	90	5A		01011010
remember[sp]	286	811E	10000001	00011110
ever[sp]	234	80EA	10000000	11101010
having[sp]	372	8174	10000001	01110100
seen[sp]	400	8190	10000001	10010000
such[sp]	441	81B9	10000001	10111001

```
a                                       40                  28                00101000
[sp]                                     1                  01                00000001
thing                                16539                C09B        11000000 10011011
.                                       15                  0F                00001111

REF# 0600 [600 chars]              Uncompressed  Huffman  LD-Based
=========================================================================
Bits:                                      4200     2768      1768
Bits Per Input Char:                       7.00     4.61      2.95
Transmission Bits:                         4880     3272      2112
Transmission Bits Per Input Char:          8.13     5.45      3.52
Number of SMS Messages:                       4        3         2
Characters per SMS:                      150.00   200.00    300.00


Experimental:  JNI_OnLoad called.
```

Appendix H - Printout Ref# 0723

```
Details
========================================
GSM Modem SerialPort: /dev/ttyUSB0
PhoneNumber: 07894555501
Message: We understand it still that there is no easy road to freedom. We know it well that
none of us acting alone can achieve success. We must therefore act together as a united
people, for national reconciliation, for nation building, for the birth of a new world. Let
there be justice for all. Let there be peace for all. Let there be work, bread, water and
salt for all. Let each know that for each the body, the mind and the soul have been freed to
fulfill themselves. Never, never and never again shall it be that this beautiful land will
again experience the oppression of one by another and suffer the indignity of being the skunk
of the world. Let freedom reign. The sun shall never set on so glorious a human achievement!

Starting...

Stable Library
=========================================
Native lib Version = RXTX-2.1-7
Java lib Version   = RXTX-2.1-7
Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CMGS=154
Rx: >
Tx:
0051000B817098545505F100F4FF8C0500030402010060812 64B80DC4A80814F55820883E347C8B10F0160524B664
A82F54C80AB8423817F769B7BC93B0F016081468E7D831B8121808A280188AEC0B60D01548833EC7B0D0154926BC3
A60D01544887534C28018117C1470F0180BE80815C860154C0410F0180BE80815C850A54C0410F0180BE80815CC0C
F0D01CBA90D01829C498E7554C0410F#
Rx: +CMGS: 64
Rx: OK
Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CMGS=145
Rx: >
Tx:
0051000B817098545505F100F4FF830500030402020180BE81A7524A5481A748C2860D014881344948846256809EA
26B479D99C6AE0F01C08C0D0180B04980B080E1838B4B5C4A5181E285E6808F80E184EE48BE7C4C808280C7813F49
8A274830352B302E35303B40014C811848B1514C48C1470F0180BE88D5E4CE0F01488654838B80B082055D6396142
8018355E84402#
Rx: +CMGS: 65
Rx: OK

Sending done!

Waiting 60 seconds before trying to read message. This gives it time to be delivered from the
GSM network...
OK, here we go.

Tx: ATE0
Rx: OK
Tx: AT+CGMI
Rx: SIEMENS
Rx: OK
Tx: AT+GMM
Rx: TC35i
```

```
Rx: OK
Tx: AT+CMGF=0
Rx: OK
Tx: AT+CPMS?
Rx: +CPMS: "ME",2,25,"SM",0,50,"SM",0,50
Rx: OK
Tx: AT+CMGR=1
Rx: +CMGR: 0,,159
Rx:
07914487200030234 40C9144874955551000F4900192819504008C0500030402010060812 64B80DC4A80814F55820
883E347C8B10F0160524B664A82F54C80AB8423817F769B7BC93B0F016081468E7D831B8121808A280188AEC0B60D
01548833EC7B0D0154926BC3A60D01544887534C28018117C1470F0180BE80815C860154C0410F0180BE80815C850
A54C0410F0180BE80815CC0CF0D01CBA90D01829C498E7554C0410F
Rx: OK

Found Unread Message:
07914487200030234 40C9144874955551000F4900192819504008C0500030402010060812 64B80DC4A80814F55820
883E347C8B10F0160524B664A82F54C80AB8423817F769B7BC93B0F016081468E7D831B8121808A280188AEC0B60D
01548833EC7B0D0154926BC3A60D01544887534C28018117C1470F0180BE80815C860154C0410F0180BE80815C850
A54C0410F0180BE80815CC0CF0D01CBA90D01829C498E7554C0410F
Tx: AT+CMGR=2
Rx: +CMGR: 0,,150
Rx:
07914487200030234 40C9144874955551000F4900192819525008305000304020201 80BE81A7524A5481A748C2860
D014881344948846256809EA26B479D99C6AE0F01C08C0D0180B04980B080E1838B4B5C4A5181E285E6808F80E184
EE48BE7C4C808280C7813F498A274830352B302E35303B40014C811848B1514C48C1470F0180BE88D5E4CE0F01488
654838B80B082055D63961428018355E84402
Rx: OK

Found Unread Message:
07914487200030234 40C9144874955551000F4900192819525008305000304020201 80BE81A7524A5481A748C2860
D014881344948846256809EA26B479D99C6AE0F01C08C0D0180B04980B080E1838B4B5C4A5181E285E6808F80E184
EE48BE7C4C808280C7813F498A274830352B302E35303B40014C811848B1514C48C1470F0180BE88D5E4CE0F01488
654838B80B082055D63961428018355E84402

Delete all messages in store as part of housekeeping

Tx: AT+CMGD=1
Rx: OK
Deleted message at index 1
Tx: AT+CMGD=2
Rx: OK
Deleted message at index 2

Decompressed Message: we understand it still that there is no easy road to freedom. we know
it well that none of us acting alone can achieve success. we must therefore act together as a
united people, for national reconciliation, for nation building, for the birth of a new
world. let there be justice for all. let there be peace for all. let there be work, bread,
water and salt for all. let each know that for each the body, the mind and the soul have been
freed to fulfill themselves. never, never and never again shall it be that this beautiful
land will again experience the oppression of one by another and suffer the indignity of being
the skunk of the world. let freedom reign. the sun shall never set on so glorious a human
achievement!

Receiving done!

Please wait, generating report...
Report generated.

SMS Compression Report
==================================================

REF# 0723

Text Message [723 characters]: We understand it still that there is no easy road to freedom.
We know it well that none of us acting alone can achieve success. We must therefore act
together as a united people, for national reconciliation, for nation building, for the birth
of a new world. Let there be justice for all. Let there be peace for all. Let there be work,
bread, water and salt for all. Let each know that for each the body, the mind and the soul
have been freed to fulfill themselves. Never, never and never again shall it be that this
beautiful land will again experience the oppression of one by another and suffer the
indignity of being the skunk of the world. Let freedom reign. The sun shall never set on so
glorious a human achievement!

Words Not Found in Dictionary [99.00 percent hit ratio]
==================================================
indignity

Dictionary Symbol        Dictionay Index  Encoded Hex Byte(s)  Encoded Binary Byte(s)
```

[compression indicator]	0	00		00000000
we[sp]	96	60		01100000
understand[sp]	294	8126	10000001	00100110
it[sp]	75	4B		01001011
still[sp]	220	80DC	10000000	11011100
that[sp]	74	4A		01001010
there[sp]	129	8081	10000000	10000001
is[sp]	79	4F		01001111
no[sp]	85	55		01010101
easy[sp]	520	8208	10000010	00001000
road[sp]	995	83E3	10000011	11100011
to[sp]	71	47		01000111
freedom	18609	C8B1	11001000	10110001
.	15	0F		00001111
[sp]	1	01		00000001
we[sp]	96	60		01100000
know[sp]	82	52		01010010
it[sp]	75	4B		01001011
well[sp]	102	66		01100110
that[sp]	74	4A		01001010
none[sp]	757	82F5	10000010	11110101
of[sp]	76	4C		01001100
us[sp]	171	80AB	10000000	10101011
acting[sp]	1059	8423	10000100	00100011
alone[sp]	383	817F	10000001	01111111
can[sp]	118	76		01110110
achieve[sp]	7035	9B7B	10011011	01111011
success	18747	C93B	11001001	00111011
.	15	0F		00001111
[sp]	1	01		00000001
we[sp]	96	60		01100000
must[sp]	326	8146	10000001	01000110
therefore[sp]	3709	8E7D	10001110	01111101
act[sp]	795	831B	10000011	00011011
together[sp]	289	8121	10000001	00100001
as[sp]	138	808A	10000000	10001010
a	40	28		00101000
[sp]	1	01		00000001
united[sp]	2222	88AE	10001000	10101110
people	16566	C0B6	11000000	10110110
,	13	0D		00001101
[sp]	1	01		00000001
for[sp]	84	54		01010100
national[sp]	2099	8833	10001000	00110011
reconciliation	27771	EC7B	11101100	01111011
,	13	0D		00001101
[sp]	1	01		00000001
for[sp]	84	54		01010100
nation[sp]	4715	926B	10010010	01101011
building	17318	C3A6	11000011	10100110
,	13	0D		00001101
[sp]	1	01		00000001
for[sp]	84	54		01010100
the[sp]	72	48		01001000
birth[sp]	1875	8753	10000111	01010011
of[sp]	76	4C		01001100
a	40	28		00101000
[sp]	1	01		00000001
new[sp]	279	8117	10000001	00010111
world	16711	C147	11000001	01000111
.	15	0F		00001111
[sp]	1	01		00000001
let[sp]	190	80BE	10000000	10111110
there[sp]	129	8081	10000000	10000001
be[sp]	92	5C		01011100
justice[sp]	1537	8601	10000110	00000001
for[sp]	84	54		01010100
all	16449	C041	11000000	01000001
.	15	0F		00001111
[sp]	1	01		00000001
let[sp]	190	80BE	10000000	10111110
there[sp]	129	8081	10000000	10000001
be[sp]	92	5C		01011100
peace[sp]	1290	850A	10000101	00001010
for[sp]	84	54		01010100
all	16449	C041	11000000	01000001
.	15	0F		00001111
[sp]	1	01		00000001

let[sp]	190	80BE	10000000 10111110
there[sp]	129	8081	10000000 10000001
be[sp]	92	5C	01011100
work	16591	C0CF	11000000 11001111
,	13	0D	00001101
[sp]	1	01	00000001
bread	19369	CBA9	11001011 10101001
,	13	0D	00001101
[sp]	1	01	00000001
water[sp]	668	829C	10000010 10011100
and[sp]	73	49	01001001
salt[sp]	3701	8E75	10001110 01110101
for[sp]	84	54	01010100
all	16449	C041	11000000 01000001
.	15	0F	00001111
[sp]	1	01	00000001
let[sp]	190	80BE	10000000 10111110
each[sp]	423	81A7	10000001 10100111
know[sp]	82	52	01010010
that[sp]	74	4A	01001010
for[sp]	84	54	01010100
each[sp]	423	81A7	10000001 10100111
the[sp]	72	48	01001000
body	17030	C286	11000010 10000110
,	13	0D	00001101
[sp]	1	01	00000001
the[sp]	72	48	01001000
mind[sp]	308	8134	10000001 00110100
and[sp]	73	49	01001001
the[sp]	72	48	01001000
soul[sp]	1122	8462	10000100 01100010
have[sp]	86	56	01010110
been[sp]	158	809E	10000000 10011110
freed[sp]	8811	A26B	10100010 01101011
to[sp]	71	47	01000111
fulfill[sp]	7577	9D99	10011101 10011001
themselves	18094	C6AE	11000110 10101110
.	15	0F	00001111
[sp]	1	01	00000001
never	16524	C08C	11000000 10001100
,	13	0D	00001101
[sp]	1	01	00000001
never[sp]	176	80B0	10000000 10110000
and[sp]	73	49	01001001
never[sp]	176	80B0	10000000 10110000
again[sp]	225	80E1	10000000 11100001
shall[sp]	907	838B	10000011 10001011
it[sp]	75	4B	01001011
be[sp]	92	5C	01011100
that[sp]	74	4A	01001010
this[sp]	81	51	01010001
beautiful[sp]	482	81E2	10000001 11100010
land[sp]	1510	85E6	10000101 11100110
will[sp]	143	808F	10000000 10001111
again[sp]	225	80E1	10000000 11100001
experience[sp]	1262	84EE	10000100 11101110
the[sp]	72	48	01001000
oppression[sp]	15996	BE7C	10111110 01111100
of[sp]	76	4C	01001100
one[sp]	130	8082	10000000 10000010
by[sp]	199	80C7	10000000 11000111
another[sp]	319	813F	10000001 00111111
and[sp]	73	49	01001001
suffer[sp]	2599	8A27	10001010 00100111
the[sp]	72	48	01001000
i	48	30	00110000
n	53	35	00110101
d	43	2B	00101011
i	48	30	00110000
g	46	2E	00101110
n	53	35	00110101
i	48	30	00110000
t	59	3B	00111011
y	64	40	01000000
[sp]	1	01	00000001
of[sp]	76	4C	01001100
being[sp]	280	8118	10000001 00011000
the[sp]	72	48	01001000
skunk[sp]	12625	B151	10110001 01010001

```
of[sp]                                  76                  4C               01001100
the[sp]                                 72                  48               01001000
world                                16711                C147       11000001 01000111
.                                       15                  0F               00001111
[sp]                                     1                  01               00000001
let[sp]                                190                 80BE       10000000 10111110
freedom[sp]                           2261                 88D5       10001000 11010101
reign                                25806                E4CE       11100100 11001110
.                                       15                  0F               00001111
[sp]                                     1                  01               00000001
the[sp]                                 72                  48               01001000
sun[sp]                               1620                8654       10000110 01010100
shall[sp]                              907                 838B       10000011 10001011
never[sp]                              176                 80B0       10000000 10110000
set[sp]                                517                 8205       10000010 00000101
on[sp]                                  93                  5D               01011101
so[sp]                                  99                  63               01100011
glorious[sp]                          5652                9614       10010110 00010100
a                                       40                  28               00101000
[sp]                                     1                  01               00000001
human[sp]                              853                 8355       10000011 01010101
achievement                          26692                E844       11101000 01000100
!                                        2                  02               00000010

REF# 0723 [723 chars]              Uncompressed  Huffman  LD-Based
=============================================================================
Bits:                                    5061     3016      2064
Bits Per Input Char:                     7.00     4.17      2.85
Transmission Bits:                       5912     3520      2408
Transmission Bits Per Input Char:        8.18     4.87      3.33
Number of SMS Messages:                     5        3         2
Characters per SMS:                    144.60   241.00    361.50


Experimental:  JNI_OnLoad called.
```