1-1-2010

Call Admission Control Scheme for the IEEE 802.16e at Vehicular Speeds

Iftekhar Ahmad
Edith Cowan University

Daryoush Habibi
Edith Cowan University

10.1109/HPCC.2010.81
This is an Author's Accepted Manuscript of: Ahmad, I., & Habibi, D. (2010). Call Admission Control Scheme for the IEEE 802.16e at Vehicular Speeds. Proceedings of IEEE International Conference on High Performance Computing and Communications. (pp. 413-418). Melbourne, Australia. IEEE .

2010 12th IEEE International Conference on High Performance Computing and Communications

Call Admission Control Scheme for the IEEE 802.16e at Vehicular Speeds

Iftekhar Ahmad
Centre for Communications Engineering Research,
Edith Cowan University, Australia
E-mail: i.ahmad@ecu.edu.au

Daryoush Habibi
Centre for Communications Engineering Research,
Edith Cowan University, Australia
E-mail: d.habibi@ecu.edu.au

Abstract— **The IEEE 802.16e standard has emerged as an exciting mobile wireless broadband technology that promises to deliver both high throughput and guaranteed quality of service (QoS). Call admission control (CAC) scheme serves as a great utility for WiMAX, which ensures that resources are not overcommitted and thereby, all existing connections enjoy guaranteed quality of service. Existing CAC schemes largely depend on computation of available resources while making an acceptance or rejection decision once a new request arrives. Since wireless channels are not as reliable as wired communication, CAC scheme in WiMAX communication faces a serious challenge of making a right estimate of the usable channel capacity while computing the available resources at various communication scenarios. Existing CAC schemes do not consider the impact of mobility at vehicular speeds when computing the usable link capacity and available resources. In this paper, we propose a new CAC scheme that estimates the usable link capacity for WiMAX communication at various vehicular speeds and uses this information while making a CAC decision. Extensive simulation results show that the proposed scheme achieves lower dropping rate and improved QoS compared to existing schemes.**

Keywords- WiMAX, throughput, quality of service, call admission control, vehicular speeds.

I. INTRODUCTION

Wireless communication has enjoyed an extraordinary growth and progressive spread in our daily life. The IEEE 802.11 standard has been the leading wireless communication technology and a huge commercial success [1]. Despite the widespread penetration of the 802.11, the need for further improvement in the wireless transmission rate and QoS was realized, which has led to the introduction of another family of standards, termed as the IEEE 802.16 [12]. Many researchers today advocate the IEEE 802.16, also commonly known as WiMAX, as the futuristic solution to wired broadband infrastructure for hard-to-reach areas like rural or urban places. A key feature of the WiMAX technology is its ability to offer guaranteed QoS. Features like traffic classification, connection oriented service and tools like QoS-aware medium access control (MAC) scheduler and CAC schemes have been adopted in the 802.16 family of standards as a mechanism to provided guaranteed QoS to the end applications.

The CAC scheme plays an important role in QoS provisioning in the 802.16 family. WiMAX uses connection oriented MAC and all subscriber stations (SS) need to request for a connection to the BS before they can actually transmit/receive any data. The BS upon receiving the request checks whether the available resources are sufficient to support the requested service without degrading the QoS of other on-going connections. This proactive mechanism is governed by a scheme known as call admission control or CAC. One of the fundamental working principles of all CAC scheme is that, in QoS-aware communication, a high blocking rate is more desirable over a high dropping rate. As an acknowledgement of CAC scheme's importance in QoS provisioning, researchers have been working to design and improve CAC schemes in WiMAX communication.

Wang *et al.* [2] proposed a dynamic CAC for the fixed WiMAX (802.16d) standard, which uses bandwidth reservation and degradation policies. Bandwidth reservation is governed by the traffic priority and degradation is the method of decreasing the bandwidth allocated to admitted connections once the useful channel capacity decreases. Initially when the available channel capacity is in the higher side, connections were given the maximum amount of bandwidth. Bandwidth per connection is gradually decreased as the number of connections increases, resulting lower amount of available bandwidth. Authors showed that through adaptation of a degradation scheme, it is possible to lower the blocking rate and increase the utilization. This CAC scheme was designed for fixed WiMAX and the authors did not consider the impact of mobility on usable channel capacity when a decision is made during the CAC process. Wang *et al.* [3] proposed a CAC scheme for the 802.16e standard, which assigns higher priority to the handoff connections compared to the newly originating connections using guard channel schemes. Ge *et al.* [4] proposed another CAC scheme for the 802.16e standard, that uses the bandwidth degradation model and admits a newly arriving connection only when no admitted connection is degraded and requested bandwidth is met. Rong *et al.* [5] proposed a CAC scheme for WiMAX communication that adopts two separate policies for admitting uplink connections and downlink connections. The idea was to increase the fairness and utility of connections. In [6] and [7], the authors proposed a scheduling algorithm to complement a CAC scheme for the 802.16d standards.

All of the above mentioned CAC schemes considered currently available bandwidth while making a decision whether to accept or reject a newly arriving incoming call. One of the major problems with mobile WiMAX communication is that usable throughput becomes

978-0-7695-4214-0/10 $26.00 © 2010 IEEE
DOI 10.1109/HPCC.2010.81

IEEE computer society

significantly low when the subscriber station (SS) moves at vehicular speeds. A CAC decision that is made based on available throughput, computed when the SS moves at low vehicular speeds (or at stationary position), may prove very costly when the SS reaches its top speed. To the best knowledge of the authors, none of the existing CAC schemes consider this issue of low usable throughput at high vehicular speeds while making a CAC decision. In this work, we show that an estimate of usable throughput at various vehicular speeds can be made in advance for WiMAX communication and, based on this information, a more informed CAC decision can be made, which offers higher quality of service for the end applications.

II. CALL ADMISSION CONTROL FOR WIMAX COMMUNICATION AT VEHICULAR SPEED

The mobile WiMAX (802.16e) standard includes the air interfaces for fixed and mobile broadband wireless access. The standard contains technical specifications in relation to the convergence sublayer (CS), medium access control (MAC) layer, and physical layer (PHY) [8]. The theoretical capacity of the IEEE 802.16e is 70 Mbps over a 112.6 km range. This capacity however, is hard to achieve in most practical cases and in practice, the IEEE 802.16e is capable of delivering up to 10 Mbps at around 10 km for the line-of-sight range. This throughput decreases further when the SS moves at various vehicular speeds through different environments. As common in wireless communications, many objects in the environment surrounding a transmitter and receiver act as reflectors of the original radio signal, which create multiple paths that the original signal can traverse causing the receiver to experience the overlapping of multiple copies of the transmitted signal, each traversing a different path and having differences in attenuation, delay and phase shift while travelling from the source to the receiver. Such overlapping of signals cause interference either amplifying or attenuating the signal power received at the receiver known as fading problem. Although OFDM in the 802.16e is equipped with the ability to utilize the guard channel (GI) to reduce the impact of inter-symbol interference (ISI) caused by multipath transmissions, multiple access of users and multipath fading can still cause significant deterioration in network performances, especially when the end nodes move at vehicular speed and the carrier frequency is in the lower range. Fading problem causes error in bits absorbed by the receiver and therefore, probability of bit error becomes higher at increasing speeds, limiting the usable throughput.

As discussed in the previous section, the WiMAX technology was designed with QoS in mind and CAC scheme is an important mechanism in the QoS architecture that prevents over commitment of available resources. Let us consider a SS that is currently (at time t) moving at a speed of v_t. The maximum speed the SS can reach is v_{max} and there are currently n numbers of QoS sensitive connections, consuming a total of B_t amount (in Mbps) of usable throughput. A new connection request has arrived with a demand of b Mbps. Without loss of generality, the CAC scheme can be considered as a mechanism that accepts the connection if and only if the following condition is satisfied:

$$C \geq b + B_t \tag{1}$$

The usable capacity C varies with speed, and existing CAC scheme does not consider this aspect of WiMAX communication while making a CAC decision. When the SS increases its speed, usable capacity drops and as a result, dropping rate increases significantly, causing serious degradation of QoS. In this work, we have considered the impact of speed on usable capacity and proposed a new CAC scheme that improves the dropping rate and grade of service.

III. PROPOSED CAC SCHEME

The key idea of the proposed scheme is to estimate the usable throughput in WiMAX communication at the SS's top speed and take this information into account while making a CAC decision. It may be noted that a SS's top speed may not necessarily be determined by its actual physical/technical specification. The maximum allowed speed is often determined and regulated by public transport authorities (e.g., 110 km/hr for private vehicles and 130 km/hr for public trains at country areas in Western Australia). In our previous work [11], we showed that it is possible to derive a mathematical formulation to estimate the bit error rate at various vehicular speeds. In Section 3.*A*, we reproduce on how to calculate the estimated usable throughput at various mobile terminal speeds. In Section 3.*B*, we then show how to make a CAC decision based on the estimated usable throughput.

A. Mobile Terminal's Speed and Throughput

Rayleigh fading [9][10] is often recommended as an excellent model to represent the error in radio signal propagation caused by multipath fading when there are many objects in the environment scattering the radio signal before the receiver receives the signal. For a wireless communication channel that is characterized by the parameters: N be the number of OFDM sub carriers, fm be is the doppler frequency where $f_m = f_c(v/c)$, v be the speed of mobile nodes, c be the speed of light, f_c be the carrier frequency, T_s be the duration of each M-ary QAM symbol, E_s be the average symbol energy, E_b be the average energy per bit, N_o be the noise energy, γ_b be the received bit-energy-to-noise ratio, $\overline{\gamma}_b$ be the average received bit-energy-to-noise ratio, γ_s be the received symbol-energy-to-noise ratio, $\overline{\gamma}_s$ be the average received symbol-energy-to-noise ratio, $P_b(\gamma_b)$ be the probability of received bit error, P_P be the packet error probability. Following the rayleigh fading model [10], we can express the probability density function of received symbol energy to noise ratio as

$$p_{\gamma_s}(x) = \frac{1}{\overline{\gamma}_S} e^{-x/\overline{\gamma}_S}, \; x \geq 0 \tag{2}$$

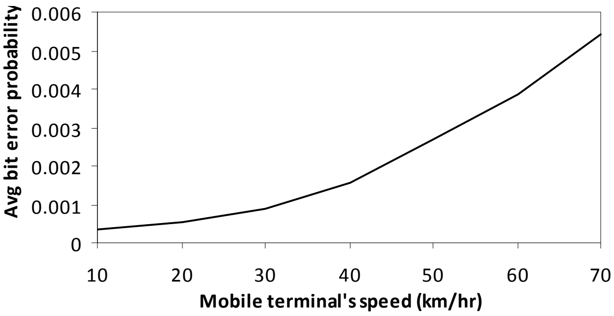

Figure 1: Average bit error probability at various mobile terminal's speed.

and the average symbol error probability for a such channel can be expressed as

$$P_M = \int_0^\infty P_M(x)\, p_{y_s}(x)\; dx \tag{3}$$

where the average received symbol-energy-to-noise ratio is given by

$$\overline{\gamma_s} = \frac{1}{1-\frac{1}{N^2}\left[N+2\sum_{i=1}^{N-1}(N-i)J_0(2\pi f_m T_s i)\right]+\frac{NT_s}{\left(E_s \big/ N_o\right)}} \tag{4}$$

Now the average received bit-energy-to-noise ratio $\overline{\gamma_b}$ can be derived from the average received symbol-energy-to-noise ratio $\overline{\gamma_s}$ according to the following equation:

$$\overline{\gamma_b} = \frac{\overline{\gamma_s}}{\log_2 M} \tag{5}$$

where M is the number of symbols for M-ary QAM modulation scheme. For 16-QAM, M equals 16 and for QPSK M is 4. Combining Eq. (4) and (5), we can express $\overline{\gamma_b}$ as

$$\overline{\gamma_b} = \frac{\frac{1}{\log_2 M}}{1-\frac{1}{N^2}\left[N+2\sum_{i=1}^{N-1}(N-i)J_0(2\pi f_m T_s i)\right]+\frac{NT_s}{\log_2 M}\left(\frac{1}{E_b \big/ N_o}\right)} \tag{6}$$

For a fixed channel with unchanged values of N, NT_s, relatively constant E_b/N_o over time and a known modulation scheme, the main source of error for a mobile terminal is the velocity v that has direct impact on f_m, which in turn influences received symbol/bit energy to noise ratio. According to the equation, higher will be the velocity, lower will be the received symbol/bit energy to noise ratio. For OFDMA air interface, the main source of bit error is the inter-carrier interference instead of interference between the OFDMA users. Additive white gaussian noise (AWGN) [10] is often used to successfully approximate the OFDMA inter-carrier interference. Taking AWGN into consideration, we can derive the bit error probability as

$$P_b = Q\left(\sqrt{2\gamma_b}\right) \tag{7}$$

where bit error probability P_b and symbol error probability P_M of OFDM are related to each other in the form of

$$P_b \approx \frac{P_M}{\log_2 M} \tag{8}$$

For M=2 or M=4, the average bit error probability is given as

$$\begin{aligned} P_b &= \int_0^\infty P_b(x)\, p_{\gamma_b}(x)\, dx \\ &= \frac{1}{2}\left[1-\sqrt{\frac{\overline{\gamma_b}}{1+\overline{\gamma_b}}}\right] \end{aligned} \tag{9}$$

and bit error probability for higher order of M at a speed of v can also be obtained from:

$$P_b(v) \approx \frac{\int_0^\infty P_M(x)\, p_{\gamma_M(v)}(x)\, dx}{\log_2 M} \tag{10}$$

For a scenario where carrier frequency f_c is 2.6 Ghz, bandwidth is 12 MHz, number of sub carriers N equals 2048, symbol period equals 149.33s, modulation scheme is QPSK and E_b/N_o equals 5 dB, the above expressions lead to a relationship between the average bit error probability and mobile terminal's speed that can be depicted as shown in Figure 1. The Figure demonstrates that higher the mobile terminals' speed, higher is the average bit error probability.

B. CAC decision based on estimated throughput at top vehicular speed

For a mobile SS with a top speed (or a maximum allowed speed) of v_{max}, it is possible to estimate the average bit error probability P_b at v_{max} from Fig. 1 or Equ. (9). For an m bit symbol, the relationship between average bit error probability and average symbol error probability P_s can be expressed as:

$$P_s(v_{\max}) = 1-\left(1-P_b(v_{max})\right)^m \tag{11}$$

For a packet comprising K symbols, number of estimated corrupted symbol Z can be computed from:

$$Z_{\max} = K \times P_S(v_{\max}) \tag{12}$$

Assuming reed-solomon (RS) code will be used for error recovery, the number of required parity symbols F can be given as:

$$F(v_{\max}) = 2 \times Z_{\max} = 2K \times P_s(v_{\max}) \tag{13}$$

A data packet has overhead in the form of a header (h) and RS code F, which will increase at higher bit error rate and vice versa. The overhead q per data bit can be expressed as:

$$q_{\max} = \left(h + F(v_{max})\right) / K \tag{14}$$

Since q per bit increases at higher vehicular speeds, this reduces the usable transmission rate when the SS reaches its top speed. Assuming C being the ideal channel capacity when the SS is at stationary position, the usable data transmission rate at v_{max} can be computed as:

$$C^* = C - q_{max}\, C \tag{15}$$

We propose to use this estimated usable transmission rate while admitting a QoS sensitive application that arrives when the SS moves at a speed v_t ($v_t \leq v_{max}$). Based on the estimated usable throughput, a CAC decision can be made as follows:

Accept a request if and only if:

$$C^* \geq b + \sum_i b_i \tag{16}$$

Where connection i requires an assurance on QoS and b_i represents the bandwidth required for supporting existing call i.

The proposed CAC scheme can be summarized as:

```
Procedure CAC_decision ($v_{max}$, $b$)
  begin
    $P_b(v_{max})$ = compute estimated average bit error probability at $v_{max}$ from the relationship as depicted in Fig. 1 obtained from using Eq. (9).
    $P_s(v_{max})$ = estimate the average symbol error probability from Eq. (11)
    $q_{max}$ = compute the overhead per data bit from Eq. (14).
    $C^*$ = compute the estimated usable channel capacity from Eq. (15).
    if $C^* \geq b + \sum_i b_i$
      then return 1 (connection should be accepted)
      else return 0 (connection must not be accepted).
  end CAC_decision ($v_{max}$, $b$).
```

IV. SIMULATION RESULTS

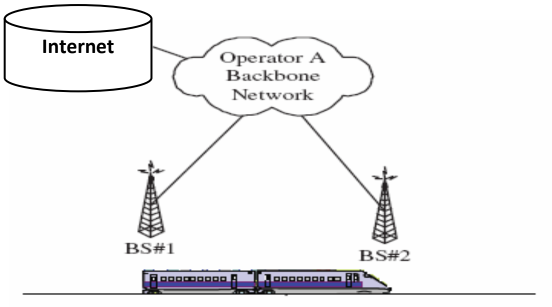

Figure 2: Simulation scenario.

The simulation was conducted in NS2 for an Internet communication service on a public train as shown in Fig. 2. The maximum data rate capacity of the WiMAX channel was 20 Mbps. The carrier frequency was 2.6 GHz with a bandwidth of 12 MHz, number of sub-carriers was 2048 and the modulation style was QPSK. Two groups of traffic were considered: first group required a guarantee on QoS and the second group was for best effort applications. Bandwidth demand for each application was uniformly distributed in the range of 128 to 512 Kbps. Arrival of connection request was assumed to follow a Poission distribution with a mean interval of 500ms. Lifetime of each connection was exponentially distributed with a mean of 60s. For the simulation scenario, the train(SS) moves from a stationary position and gradually increases its speed, reaching a speed of 40 km/hr at 60 sec and a top speed of 70km/hr at 120sec time (Fig. 3). The train continues to cruise at that speed before the train starts to slow down at 160 sec. The train continues to slow down and finally stops at the next station at 240sec. We monitored the connection dropping rate, blocking rate and overall utilization of the channel as the train moves at various speeds.

Figure 4 shows the comparison of connection dropping rate in the proposed and existing CAC schemes. The existing CAC scheme (i.e., CAC in [5]) considers the channel condition at the immediate moment when a new QoS demanding connection arrives, and computes the available resources based on the feedback information (*SNR* and P_b) sent from the BS. It does not consider the fact that the channel condition might deteriorate significantly when the SS will reach at its top speed. This is why when the train gradually increases its speed, more calls that were previously admitted based on channel state information at lower speeds, are dropped in the existing CAC scheme. The proposed scheme takes the conservative approach while admitting the QoS sensitive applications and takes the future channel condition into account. The improvement achieved in the proposed scheme is significant (about 4.5%) at around 120s time when the train reaches its top speed. Figure 5 shows the

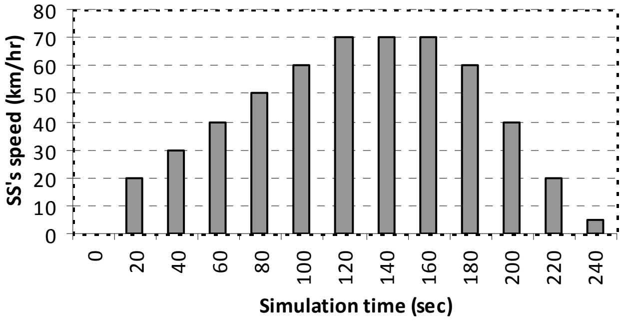

Figure 3: Vehicular speed of the moving train.

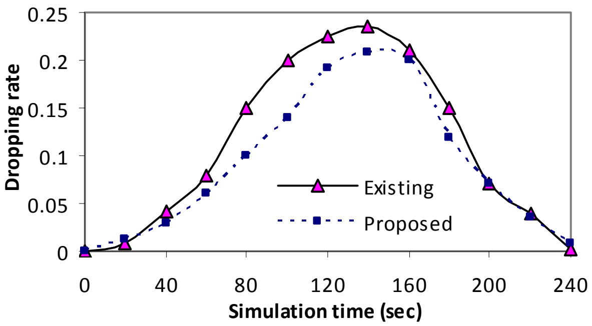

Figure 4: Comparison of call dropping rate in the proposed and standard CAC scheme.

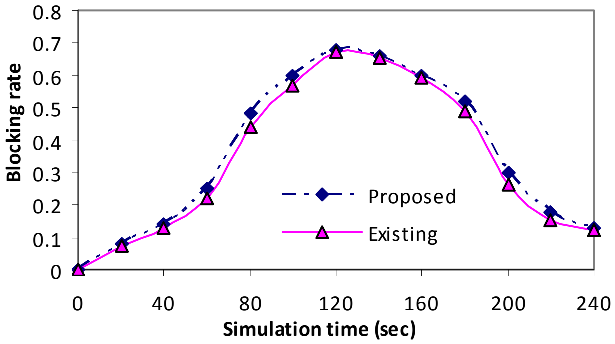

Figure 5: Comparison of call blocking rate in the proposed and standard CAC scheme.

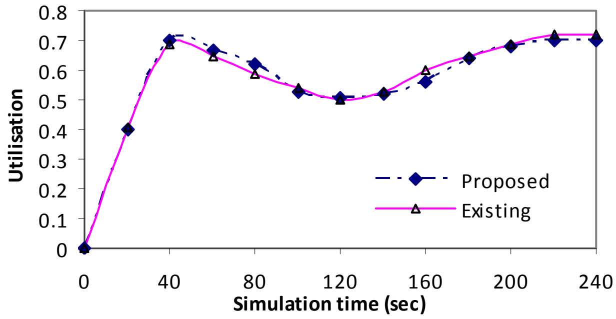

Figure 6: Comparison of bandwidth utilization in the proposed and standard CAC scheme.

call blocking rate in the proposed and existing scheme. Since the proposed scheme adopts a conservative approach during the CAC process, it blocks more call compared to the existing scheme. This is why the blocking rate is higher in the proposed scheme. This however, does not deter the merit of the proposed scheme as, for a network that is designed with QoS in mind, blocking is always considered a preferred option than admitting a connection and then dropping it. Figure 6 shows the utilisation of the channel computed as the ratio of actual transmitted throughput to the channel capacity. As evident in the figure, the proposed scheme performs comparably against the existing scheme even though it blocks more call compared to the existing scheme. This is because the proposed scheme prefers to block those connections that demand higher amount of bandwidth. As a result, calls that demand lower amount of bandwidth get more chance to access the channel, keeping the channel busy. The other reason behind a good utilisation is that best effort traffic continues to utilise the bandwidth left unused in the system, which ultimately contributes to a better channel utilisation. Utilisation as a whole drops significantly at high speeds when the bit error rate increases.

V. CONCLUSION

WiMAX is designed with QoS in mind and CAC is an integral part of WiMAX standard that aims to deliver improved QoS. Existing CAC schemes are mostly designed for fixed WiMAX communication as they do not consider the hostile channel conditions caused by mobility at high vehicular speeds. In this paper, we proposed a CAC scheme that estimates the usable channel capacity when the SS reaches its top speed, and use this information while making a CAC decision. The benefit is clearly evident in the simulation results that confirm that dropping rate improves significantly in the proposed CAC scheme. The proposed scheme performs comparably in terms of call blocking rate and channel utilization.

VI. REFERRENCES

[1] IEEE Standard Department, “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications,” IEEE standard 802.11-1997, 1997.

[2] Haitang Wang, Wei Li and Dharma P. Agrawal, “Dynamic admission control and QoS for IEEE 802.16 Wireless MAN,” Proc. Wireless Telecommunication Symposium, pp. 60-66, 2005.

[3] Liping Wang, Fuqiang Liu, and Yushend Ji, “Admission control for non-preprovisioned service flow in wireless metropolitan area networks,” Proc. Fourth European Conference on Universal Multiservice Networks, pp. 243-249, 2007.

[4] Yin Ge, Geng-Sheng Kuo, “An efficient admission control scheme for adaptive multimedia service in IEEE 802.16e networks,” Proc. IEEE Vehicular Technology Conference, VTC, pp. 1-5, 2006.

[5] Bo Rong, Yi Qian and Kejie Lu, “Call admission control optimization in WiMAX networks,” IEEE Transactions on Vehicular Technology, vol. 57, no. 4, pp. 2509-2522, July 2008.

[6] Kitti Wongthavarawat, and Aura Ganz, “Packet scheduling for QoS support in IEEE 802.16 broadband wireless access system,” International Journal of Communication Systems, vo. 16, no. 1, pp. 81-96, February 2003.

[7] Chi Hong Jiang, Tzu-Chieh Tsai, “Token bucket based CAC and packet scheduling for IEEE 802.16 broadband wireless area networks,” Proc. IEEE Consumer Communications and Networking Conference (CCNC), pp. 183-187, 2006.

[8] C. Huang, H. Juan, M. Lin and C. Chang, “Radio resource management of heterogeneous services in mobile WiMAX systems," IEEE Wireless Communications, vol. 14, no. 1, pp. 20 - 26, February 2007.

[9] T. Cooklev, Wireless Communication Standards - A Study of IEEE 802.11, 802.15 and 802.16, IEEE Press, 2004.

[10] G. L. Stuber, Principles of Mobile Communication, 2nd Edition, Boston, MA, Kluwer Acdemic Publisher, 2002.

[11] I. Ahmad and D. Habibi, “A novel mobile WiMAX solution for higher throughput,” Proc. IEEE International Conference on Networks (ICON), pp. 1-5, 2008.

[12] C. Eklund, R. B. Marks, K. L. Stanwood and S. Wang, “IEEE Standard 802.16: a technical overview of the WirelessMAN air interface for broadband wireless access,” IEEE Communications Magazine, pp. 98-107, June 2002.