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Studienarbeit:

Integration of unidirectional wireless systems within heterogeneous networks

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List of Abbreviations

3GPP	3rd Generation Partnership Project
ACK	Acknowledgment
ARP	Address Resolution Protocol
C/N	Carrier-to-Noise
CBR	Constant Bitrate
CCA	Clear Channel Assessment
CCK	Complementary Code Keying
CP	Cycle Prefix
CRC	Cyclic Redundancy Check
CSMA/CA	Carrier Sense Multiple Access With Collision Avoidance
CTS	Clear To Send
DCF	Distributed Coordination Function
DIFS	DCF Interframe Space
DL	Downlink
DSM-CC	Digital Storage Media Command And Control
DSSS	Direct-Sequence Spread Spectrum
DTCP	Digital Transmission Content Protection
DVB	Digital Video Broadcasting
DVB-H	Digital Video Broadcasting - Handheld
DVB-T	Digital Video Broadcasting - Terrestrial
EIFS	Extended InterFrame Space
ERP	Extended Rate Physical
FCH	Frame Control Channel
FDD	Frequency-Division Duplexing
FEC	Forward Error Correction
FFT	Fast Fourier Transform
FHSS	Frequency-Hopping Spread Spectrum
FTP	File Transfer Protocol
GPRS	General Packet Radio Service
GSM	Global System For Mobile Communications
IE	Information Elements
IEEE	Institute Of Electrical And Electronics Engineers
IFFT	Inverse Fast Fourier Transform
IFS	Interframe Space
IP	Internet Protocol
IPDC	Internet Protocol Datacasting
IR	Infrared
ISI	Inter-Symbol Interference
LAN	Local Area Network
LLC	Logical Link Control
MAC	Media Access Control
MAN	Metropolitan Area Network

MICS	Media Independent Command Service
MIES	Media Independent Event Service
MIH	Media Independent Handover
MIH_SAP	Media Independent Handover - Service Access Point
MIHF	Media Independent Handover Function
MIIS	Media Independent Command Service
MPE	Multi Protocol Encapsulation
MPE-FEC	Multi Protocol Encapsulation - Forward Error Correction
MPEG	Moving Picture Experts Group
NAV	Network Allocation Vector
NMS	Network Management System
NS2	Network Simulation version 2
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OSI	Open Systems Interconnection Reference Model
PHY	Physical Layer
PoA	Point of Attachment
PoS	Point of Service
PLCP	Physical Layer Convergence Procedure
PMD	Physical Medium Dependent
PPDU	PLCP Protocol Data Unit
PPM	Pulse Position Modulation
PSDU	Physical layer Service Data Unit
RED	Random Early Detection
RF	Radio Frequency
RFC	Request For Comments
RTG	Receive Transition Gap
RTS	Request To Send
SFN	Single Frequency Network
SIFS	Short Interframe Space
TCP	Transmission Control Protocol
TDD	Time-Division Duplex
TPS	Transmitter Parameter Signaling
TTG	Transmit Transition Gap
TV	Television
UDLR	Unidirectional Link Routing
UDP	User Datagram Protocol
UL	Uplink
UMTS	Universal Mobile Telecommunications System
WIMAX	Worldwide Interoperability For Microwave Access

Introduction

Mobile data networks in the recent years have been kind of networks most developed due to advantage in flexibility and price of infrastructure. Technologies like WLAN that nowadays can be found in the most of the homes, the number of hotspots has been dramatically increased and also there are implementing new technologies as WiMAX have been role out by network operators to reach more coverage and capacity in order to bringing wireless access networks near to their users.

A becoming mobile broadcast technology is DVB-H (Digital Video Broadcast – Handheld) that provide digital television, it is also interesting for operators because can achieve large number of users with minimum investment in infrastructure. Another aim of companies is to develop a heterogeneous wireless access network that users will be able to connect through the best available technology.

In order to integrate these technologies in the heterogeneous wireless environment requires to provide mechanisms to allow network's interoperability. Create a seamless and transparent inter-system handover for the users is can be possible deploying a framework developed by IEEE 802.21 group. In addition, there is a problem that has to be considered. 802.21 framework cannot work on broadcast systems, must be required to implement a mechanism called Uni-Directional Link Routing created by the IETF in order to simulate bidirectional communication in unidirectional scenarios.

First of all, in this essay, there is a description of several mobile data networks that can find on heterogeneous networks like the 802.11 family, IEEE 802.16 and the broadcast service to transmit digital television into handheld (DVB-H). In the second part, it is explained the different mechanisms to support mobility in heterogeneous unidirectional systems: IEEE 802.21 and UniDirectional Link Routing. Finally, there is practical part created by the tool "Network Simulator - NS2" simulating the traffic behavior in unidirectional systems.

1. Mobile Data Networks

Nowadays, everybody has a device for communicate through a voice call, reading the e-mails in the job or talking with friends by instant messaging. These devices are in many cases mobile so there are needed wireless networks to allow this kind of communications, separating the user connected from the static connection of a wired network.

In these types of networks, main idea is that end-points can be changing their position while the connection is established. Therefore the communication is radio, meaning total freedom of use, but it requires several extra-mechanisms, for example, implement algorithm for medium access because all the communications are shared.

Be able to communicate without any physical restriction is a characteristic demand of the society. Several areas are difficult if it is necessary implement network such as older buildings, historical places, or due to terrain i.e., somewhere there is a mountain and it is difficult to reach an area.

One important factor that is made a fast growth in these networks is due to the network medium can be find somewhere, there is no cable to connect between devices make it more flexible.

1.1. IEEE 802.11

This standard is the most possible accepted broadband wireless networking, providing the highest transmission rate among wireless technologies. 802.11 Wireless Local Area Networks is a standard of the IEEE 802 family, which is composed of a serial of specifications called IEEE 802.11a, 802.11b, 802.11g or 802.11n. The standard provides rates between 1 and 300 Mbps and operates in the unlicensed 2.4 GHz (2.4 to 2.4825 GHz) and 5 GHz (5.15 to 5.35 and 5.47 to 5.825 GHz) frequency band [1]. IEEE 802.11b specification operates in the 2.4 GHz and has maximum data rate of 11 Mbps and a range of 100 meters. IEEE 802.11a supports up to 54 Mbps maximum data rates and operates in 5 GHz unlicensed band.

802.11g works in 2.4 GHz band and operates at a maximum physical layer bit rate of 54 Mbps. The 802.11n standard achieve data rate up to 300 Mbps with a range of 100 meters.

In IEEE 802 specifications are focused on the lowest layers of the OSI model, MAC (Medium Access Control) layer and physical layer. The goal of this standard is provided services like 802.3 Ethernet network

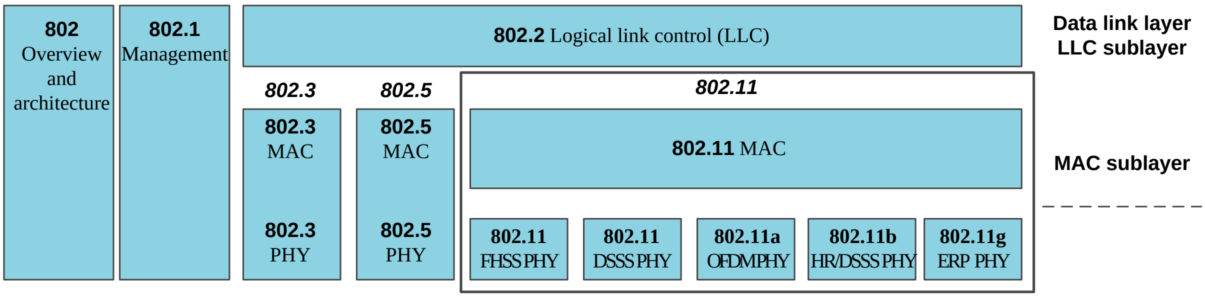


Figure 1. 802.11 OSI Model

The function of MAC is defined as mechanisms to access the medium and send data but all parameters of transmission and reception work to the PHY.

In 802.11 there are three physical layers in the initial revision of 802.11. These physical layers are: Infrared (IR), Frequency-Hopping Spread-Spectrum (FHSS) and Direct-Sequence Spread-Spectrum (DSSS). Later three physical layers based on the radio technology were developed [2]: 802.1a: Orthogonal Frequency Division Multiplexing (OFDM); 802.11b: High-Rate Direct Sequence (HR/DSSS); 802.11g: Extended Rate (ERP).

Infrared (IR) uses pulse position modulation (PPM) that employ short pulses of high peak power and low duty factor as an effective way of combating noise and also operated synchronously. Using this transmission requires absolute line of sight between the transmitter and the receiver and it is so much easy perturbed by external signals.

The Spread Spectrum techniques are designed to trade off bandwidth efficiency for reliability, integrity and security. However, more bandwidth is consumed, producing a signal is not easy to detect. That signal allows the receivers to know the parameters of the spread spectrum signal. The receiver must be tuned to the correct frequency, if not, a spread spectrum signal looks like background noise. One type of spread spectrum is Direct Sequence Spread Spectrum (DSSS) that means the narrowband signal is spread by directly multiplying it by a wideband pseudonoise code sequence or a smart code sequence known in advance to both transmitter and receiver. DSSS generates such a redundant code pattern for each data bit to be transmitted called a chip. The longer the chip pattern, the greater the probability that the original data can be recovered. Even if one or more bits in the chip patterns are damaged during the transmission, the original data can be recovered without the need of retransmission. But due to that, the data is reduced. To an unintended receiver, DSSS appears as low power wideband noise as is ignored. Another technique is to use Frequency Hopping Spread Spectrum (FHSS) that consists in hops multiple carrier frequencies in a hopping patter known to both the transmitter and the receiver. To an unintended receiver, FHSS appears being short duration impulse noise.

Standard	802.11a	802.11b	802.11g	802.11n
Transmission Technique	OFDM	DSSS	OFDM	OFDM
Frequency Band	5 GHz	2.4 GHZ	2.4 GHz	2.4 GHz or 5 GHz
Data Rate	Up to 54 Mbps	5 Mbps or 11 Mbps	Up to 54 Mbps	Up to 300 Mbps
Range	~ 35 m	~ 38 m	~ 100 m	~ 100m

Figure 2. Comparison 802.11 standards

In 802.11 LAN scenarios is composed basically of: stations, access points, wireless medium and distribution system:

- Stations: The stations are the mobile devices that interact with humans.
- Access Points: These nodes interconnect wireless side to wire side making bridge functions. It has to convert the frames to sending to other kind of networks.
- Wireless medium: Nodes have a common element, it is the medium wireless. It allows to send frames from station to station over a radio frequency layer.
- Distribution system: Provides communication between wireless network and other network.

There are two topology configurations: ad hoc and infrastructure mode.

- Ad hoc: Stations are connected directly each other. Any device acts like access point and no distribution system. All the communications are between them. It uses to configure this topology for a specific purpose in a short time period.
- Infrastructure: This network is distinguished by the use of an access point that controls an area. All the communications are established with the access point, this makes coordination actions. The stations have to associate with an access point to obtain network services. The stations send frames to the access point and then send the frame to the destination station that could be other station in the same area or any other station in different area.

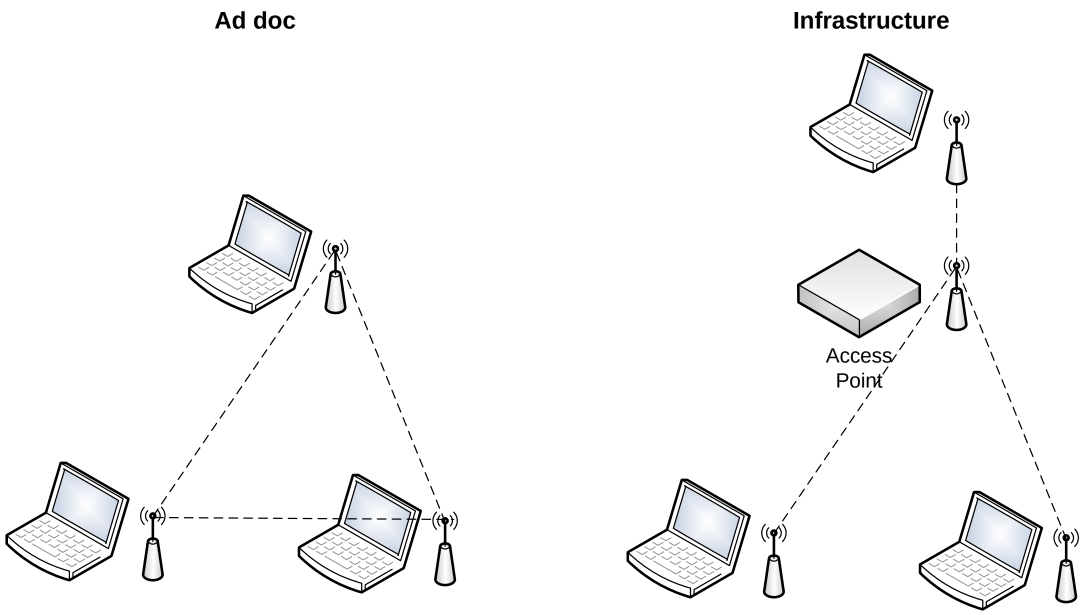


Figure 3. Ad doc and Infrastructures Topologies

1.1.1. Physical Layer

The physical layer consists of two sublayers: the Physical Layer Convergence Procedure (PLCP) sublayer and the Physical Medium Dependent (PMD). How is showed on the Figure 4, the PLCP relates the frames of the MAC and the medium transmission.

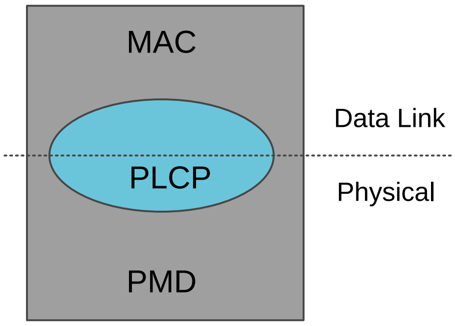


Figure 4. Physical layer logical architecture

The PMD defines the characteristics and the method of transmitting and receiving data through the wireless channel. On the other hand, the PLCP adapts the capabilities of the PMD system to the PHY service. Each PHY has defined its own PMD and PLCP. When a PSDU (Physical layer Service Data Unit) arrives at the PHY from the MAC, it arrives with a set of parameters. These parameters specify the options to be used for the transmission of the PPDU (PLCP Protocol Data Unit). The parameters are the rate to be used for the PPDU transmission, the length of the PSDU and the type of the PLCP preamble that can perform the necessary frame detection and synchronization operations. Also there are the modulation scheme and the transmit power level to be needed for the PPDU transmission. All these parameters are determined by the MAC.

A major function of the PHY is to indicate the channel status, if it is busy or idle to the MAC provided by CCA (Clear Channel Assessment). The PHY continues to sense the channel, irrespective of whether or not the station has any frame to transmit, and hence, the CCA indication is a flag to the MAC informing whether the channel is busy or idle. The CCA busy indicates that the channel is not available due to another frame transmission on the channel or unknown signal with the energy level above a threshold.

1.1.1.1. IEEE 802.11b

IEEE 802.11b, which is referred to as High-Rate (HR/DSSS), extends the DSSS by providing 5.5 Mbps and 11 Mbps data transmission rates in addition to the 1 Mbps and 2 Mbps rates. To provide the higher rates, it is used complementary code keying (CCK). The modulator refers a table that corresponds to the pattern of data bits being sent. This is the most efficient processing of the data for achieving the higher data rates 8 chip CCK is employed as the modulation scheme. The chipping rate is 11 Mchips/s, which is the same as the DSSS, thus providing the same occupied channel bandwidth.

For IEEE 802.11b standard in PLCP sublayer there are two different defined preambles and headers. The mandatory long preamble and header which is interoperable with the baseline DSSS and the optional short preamble and header. A PPDU includes a PLCP preamble, a PLCP header and a PSDU.

The long PCLP preamble and header utilize the 1 Mbps Barker code spreading with DBPSK modulation. The short preamble and header can be used optionally for the 802.11b. The short preamble and header minimize overhead, so, maximize the network throughput. The receivers that could not work with a short preamble and header, it is mandatory that the transmitter use the long PLCP preamble. The short PLCP header uses the 2 Mbps Barker code spreading with DQPSK modulation.

1.1.1.2. IEEE 802.11g

The PHY layer of this standard is related to as the Extended Rate PHY (ERP) and with OFDM. The 802.11g is combined with the 802.11b PHY and the 802.11a PHY modified to be used at the 2.5 GHz. It defines a set of mandatory transmission modes, as support the 1 Mbps and 2 Mbps rates of the DSSS modulation as 5.5 Mbps and 11 Mbps rates of the CCK modulation. Moreover, the short PPDU, which is optional for 802.11b, is mandatory for the 802.11g. An 802.11g station should be ready to detect both the 802.11b preamble and the ERP-OFDM preamble.

In 802.11.g is used Orthogonal Frequency Division Multiplexing (OFDM) such as transmission technique. Allow to achieve high data rate in fading environment dividing the spectrum in many subcarriers. The subcarriers are orthogonal among them, allowing the spectrum of each tone to overlap, so they do not interfere with each other, it means that individual carrier guard band is not necessary. Orthogonality between subcarriers is possible dividing the carrier with an integer with multiple that can make the process of the inverse of symbol duration of the parallel bit stream without causing interference among them. In Figure 5 there is shown OFDM tone.

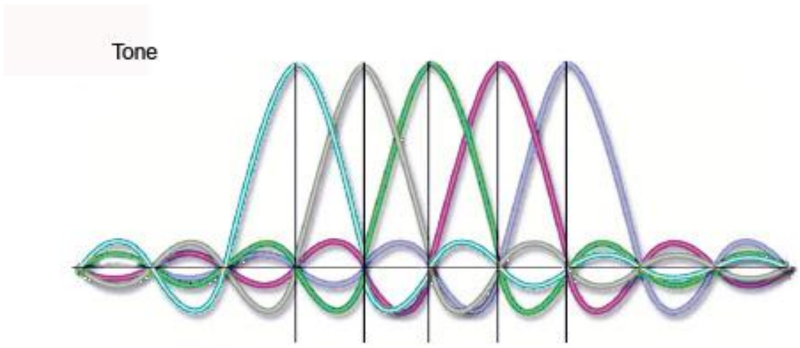


Figure 5. OFDM Tone

OFDM takes the coded signal for each sub-channel and uses Inverse Fast Fourier Transform (IFFT) in order to create a composite waveform from the strength of each sub-channel. In the receivers it takes the process inverse, it applies the Fast Fourier Transform (FFT) to a received waveform to extract the amplitude of each component subcarrier.

OFDM combat the frequency selective fading and to correct the burst errors caused by a wideband-fading channel. In channels that the time changes relatively slow, it is possible enhance the capacity by adapting the data rate in subcarriers according to the signal to noise ratio of particular subcarrier. It is due to OFDM is robust against narrow-band interference because a small percentage of the subcarriers may be affected. Moreover, in order to completely eliminate Inter-Symbol Interference (ISI) is introduced the cyclic prefix (CP) and is longer than the duration of channel delay spread. The CP is the repetition of the last samples of data portion of the block to the beginning of the data payload as showed in the next Figure 6.

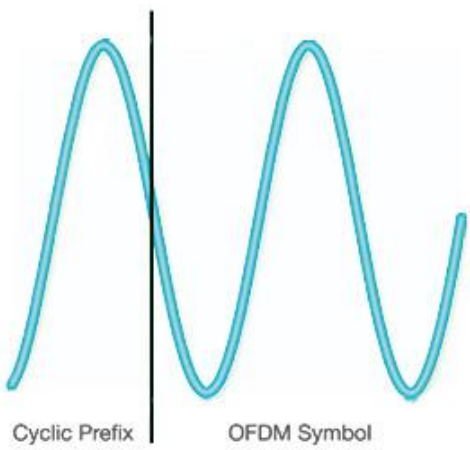


Figure 6. Cyclic Prefix

1.1.1.3. Channels

The channels are eleven for North America and fourteen for some countries or Europe. The next Figure 7 shows the 802.11 channels and their frequencies in North America.

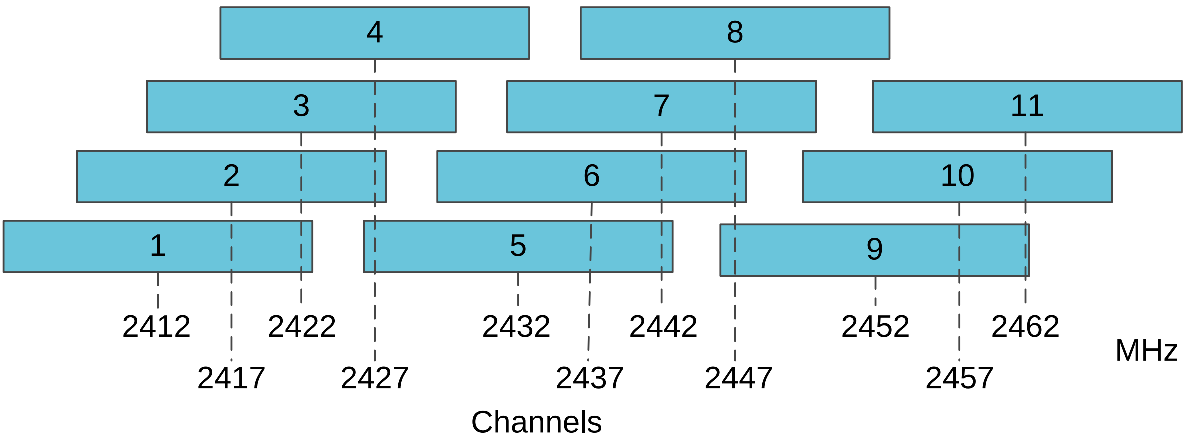


Figure 7. Channels used in North America

In 802.11 the spectrum is fixed 2.4 GHz with a bandwidth of 83.5 MHz, on each channel have a range spaced 5 MHz with its adjacent channel. The channels should be separated 25 MHz and adjacent channels should overlap among them and interfere with each other. Three of them are non-overlapping channels that the next picture shows. In North America recommend 1, 6 and 11, in Europe 1, 7 and 13 like shows the next Figure 8.

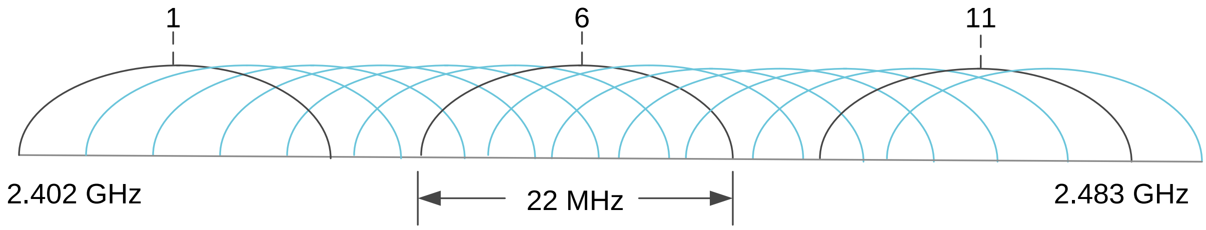


Figure 8. Channels recommend in North America

There are several recommended channels for avoid interferences from other channels that are used from others access points. It could be two kinds of interferences: co-channel interferences or adjacent interferences:

- Co-channel: It is caused by two or more different stations that transmit in the same frequency.
- Adjacent: This interference may be caused by channels that they are near other channel.

1.1.2. IEEE 802.11 Data Link Layer

The Data link layer supports several channels PHY that could be single and multiple with different characteristics. It also allows to overlap of multiple networks in the same area and same channel in a sharing medium. It is necessary to be robust for interferences such us microwaves and unlicensed signals users and co-channel interferences. There are several mechanisms for combat problems like Hidden Node or access control. This standard supports three different types of frames: data, control and management. The management frames are used for associating and disassociating with the access points and also there are frames for synchronization, authentication and deauthentication. Control frames are used for the handshake during contention period. This period is a random time that every station or node after every transmission allows equal access to the media.

802.11 uses a distributed access scheme without centralized control. The access medium is controlled by the protocol Carrier Sense Multiple Access with Collision Avoidance mechanism (CSMA/CA). This mechanism consists of first, listen to the channel for check any activity on the channel. Then, it could be two possibilities; if the medium is busy because there are some other station is transmitting, the station has to defer its transmission to later time and then try again. But if the medium is clear to transmit, a station sends a signal to all other stations that it is going to transmit and to tell also all other stations not to transmit. The collisions are avoided by using explicit packet acknowledgment call (ACK). It confirms the data packet arrived without any problem. After all the transmissions, the stations wait for this acknowledgment packet.

CSMA protocol is effective when the medium is not so much overloaded, but could be sometimes a chance of causing collision due to most of stations simultaneously sensing the medium as being free and transmitting at the same time.

In WLAN the access to the wireless medium is controlled by coordination functions that are designed for asynchronous data transport. Coordination functions are defined: the mandatory Distributed Coordination Function (DCF) and the optional Point Coordination Function (PCF). The DCF works for a distribution channel access and it has been the most domination form of the 802.11 MAC, while the PCF was difficultly implemented.

Distributed Coordination Function (DCF) model provides fair access in the environment and can bring in option of prioritized access. A mobile station can transmit in the medium when the medium is idle after an Interframe Space period (IFS). Waiting this time guarantees fair access and minimizes the collisions. For support prioritized access to allow higher priority data and management traffic is required using different IFS for set different levels of priority. There are defined IFS periods that mobile stations use:

- SIFS: This time is the shortest IFS. It is used for the highest-priority transmissions. The transmissions can start once SIFS has elapsed. A high priority can be acknowledgment data or management traffic that an Access Point sends.
- DIFS: Distributed-coordination-functions IFS. It is the minimum medium idle time for contention-based services. If the medium has been free for a period longer than this time, stations might have access to it in a short time.

- EIFS: It is the Extended Interframe Space and is used only when it has produced an incomplete or erroneous frame.

The acknowledgment is sent at the end of every packet received so if it has been successfully received, it will returns an ACK packet after check CRC. It is sent like high priority packet using SIFS period.

In Network Allocation Vector and RTS/CTS Function, the functions RTS and CTS reduce the effect of hidden terminals, provide a fast transmission check and minimize collisions as well. The hidden node is caused when there are three or more nodes. A station cannot communicate directly because there is a collision in the station between the endpoints preventing it. The endpoints 1 and 3 don not have any indication of error because the collision was local on node 2. This Figure 9 shows the hidden node problem.

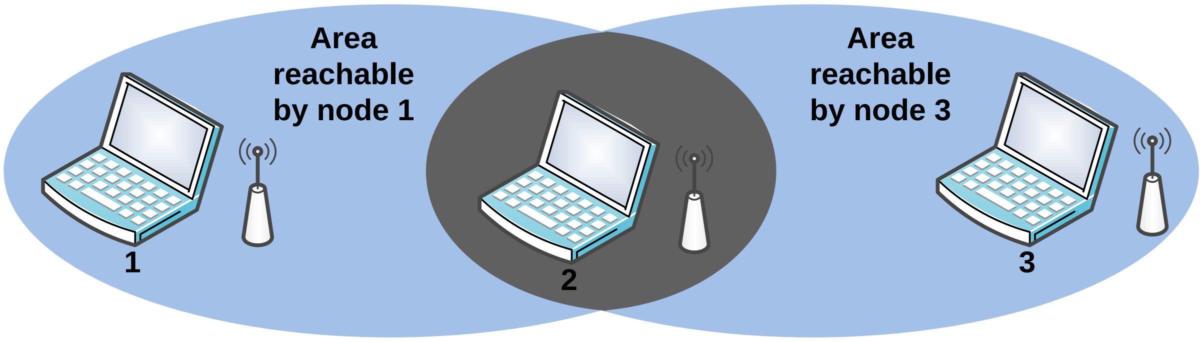


Figure 9. Hidden Node

RTS and CTS signals make clear out an area. When a station wants to send data, it initiates the process by sending an RTS frame. RTS reserves the medium for transmission and silences any stations that hear it. The target station that receives an RTS, responds with CTS. Also it makes the functions of silences to the nearby stations. After that the station can transmit without any problem of collision from hidden nodes. When this process is terminated, the frames have to be acknowledged.

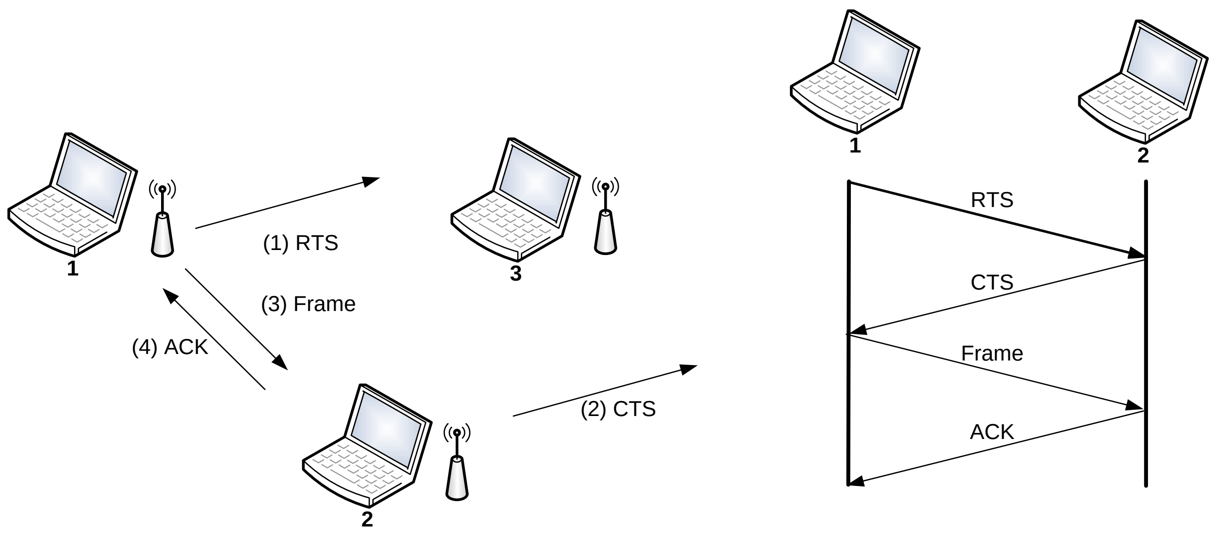


Figure 10. RTS/CTS clearing

Most of 802.11 frames carry a duration field. It can be used to reserve the medium for a determined time. The Network Allocation Vector (NAV) is a timer that indicates the time the medium will be reserved. The stations will not see the channel idle until NAV will expire so any stations want access in this time cannot do it.

The first node set the NAV in its RTS to ensure the sequence is not interrupted. Also CTS includes a short NAV to prevent access medium to other stations. After the sequence completes, the medium can be used after DIFS time. This sequence is showed in the Figure 11:

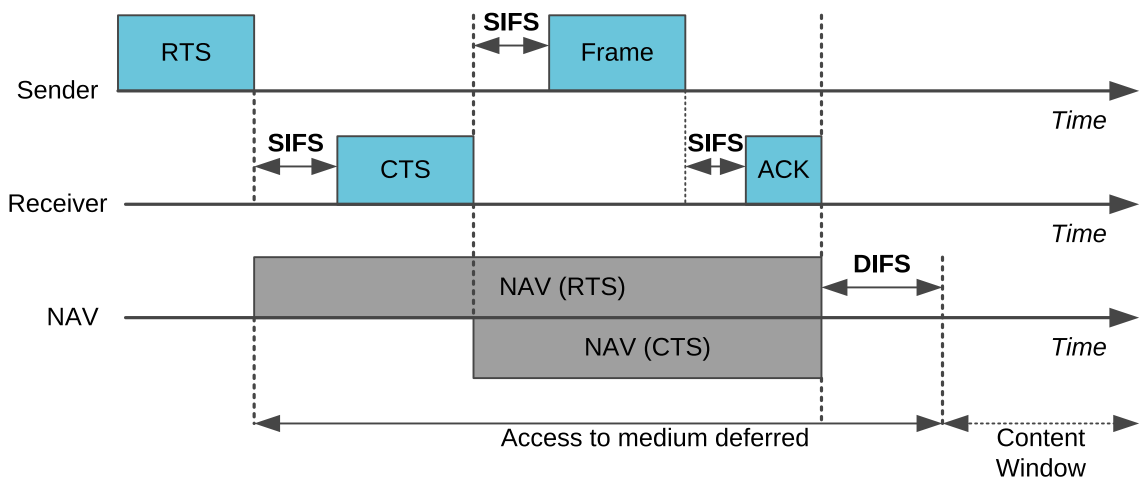


Figure 11. Using NAV

1.2. IEEE 802.16

WiMAX "Worldwide Inter-operability for Microwave Access" is a wireless technology that provides wireless last mile broadband access in the Metropolitan Area Network (MAN). It has more coverage than Wireless LAN.

In the standards of IEEE 802.16 family supported fixed and mobile WiMAX. The first standard was approved in 2001 and it works among in 10 and 60 GHz range of spectrum. Later was completed IEEE 802.16a, works in the 2 to 11 GHz band. In 2004 was designed IEEE 802.16-2004 for fixed wireless communications and in 2005 IEEE 802.16e standard was created to provide mobility support in cellular [3].

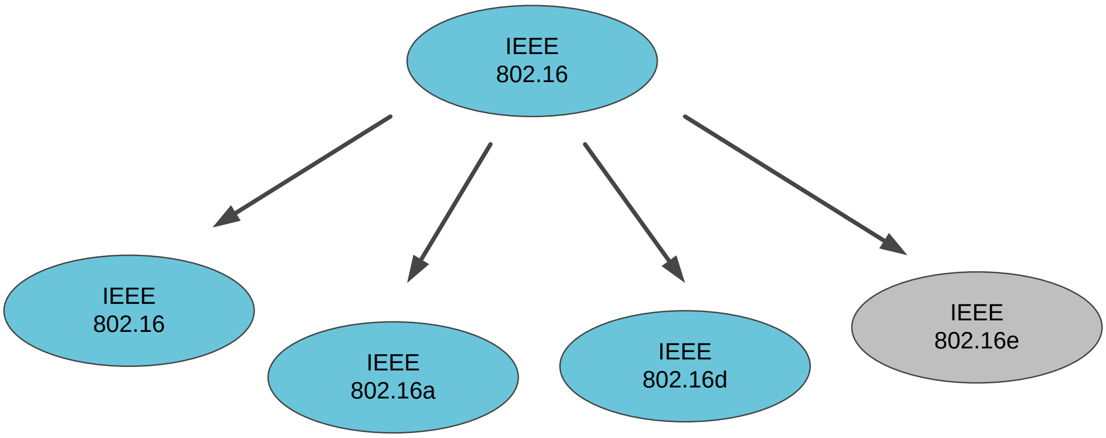


Figure 12. IEEE 802.16 standards

Mobile WiMAX is the convergence of mobile and fixed broadband networks in a common wide are broadband radio access technology and adopt Orthogonal Frequency Division Multiple Access (OFDMA) to fight against multi-path problems.

1.2.1. IEEE 802.16 Physical Layer

OFDMA is a multiple access technique based on OFDM that a carrier or more sub-carriers are allocated each user so the users share the bandwidth. OFDM symbol could be transmitted using different sub-carriers groups. OFDMA symbol structure consists of three types of sub-carriers.

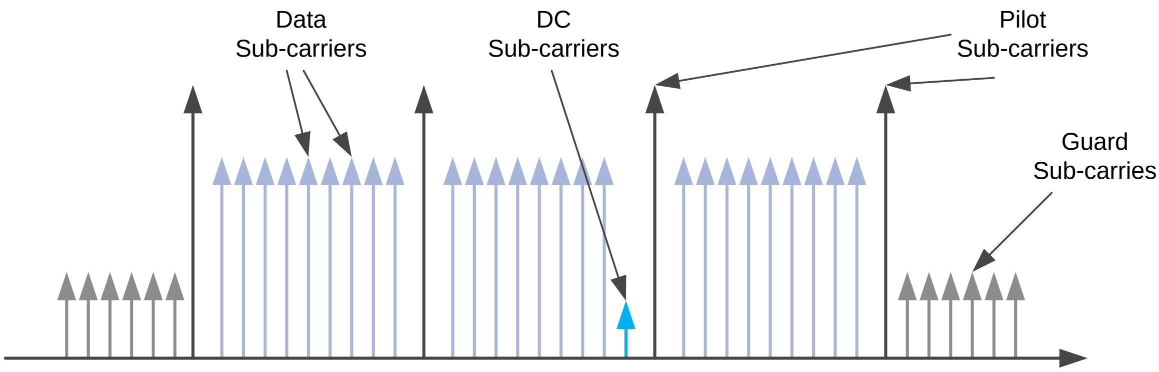


Figure 13. OFDMA

- Data sub-carrier: These sub-carriers are used for data transmission.
- Pilot sub-carrier: It makes synchronization functions.
- Null sub-carrier: Provides null data and it uses for guard band and DC carrier.

Active sub-carriers (data and pilot) are grouped in sub-groups called sub-channels. The channel could be formed with adjoin sub-carriers or not.

In this layer, WiMAX allows sub-channelling in the both links: upload (UL) and download (DL). For make sub-channelization there are two types of sub-carriers permutations; diversity and contiguous. If it takes sub-carriers pseudo-randomly to create the sub-channel, the permutation is diversity, but it is contiguous, if there are block of contiguous sub-carriers to form a sub-channel. Generally, in mobile applications perform well diversity sub-carriers but in fixed or low mobility applications are better contiguous sub-carries.

1.2.2. IEEE 802.16 Data Link Layer

This layer supports time division duplex (TDD) and frequency division duplex (FDD) for control the medium. FDD uses frequencies different carries frequencies for transmitter and receiver. The spectrum is divided in one part for upload and other part for download that means the user can send and receive a transmission at the same time. TDD divides upload link and download link in time. It utilizes just a unique and useful transmission frequency and for communication processes characterized by unbalanced information flow, so many applications use this transmission like Internet. For this reason is TDD is preferred and some more reasons:

- TDD allows an efficiently adjustment of downlink and uplink, while FDD always have fixed downlink and uplink.
- TDD supports better MIMO and smart antennas instead of FDD.
- TDD just needs a single channel for uplink and downlink, and FDD requires a pair of channels.
- Devices having FDD are more expensive and more complex than the ones with TDD.

A frame TDD is divided in DL sub-frame and UL sub-frame. Between theses sub-frames there are transition gaps; RTG (Receive Transition Gap) and TTG (Transmit Transition Gap). It is needed this time to switch the transmission modes and prevent transmissions collisions. The first part of the frame is composed by uplink sub-frame follows the downlink sub-frame. Moreover each sub-frame is divided also in slots for allocation multiple users. The next Figure 14 shows OFDMA frame in TDD mode.

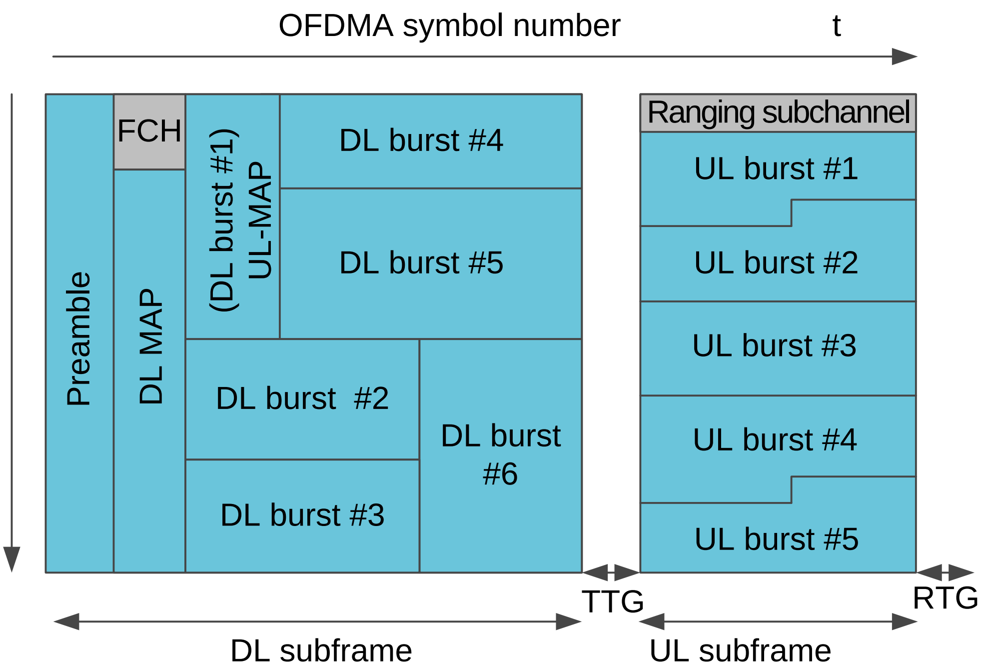


Figure 14. WiMAX frame

The DL sub-frame is composed for the following parts. The first symbol is the Synchronization and channel estimation and can be used for synchronization and channel estimation. Frame Control Channel (FCH) provides the frame configuration information as such MAP message length, encoding and sub-channels used. The DL_MAP and UL_MAP messages are used for allocation DL and UL sub-channel, control information, modulation and coding if each data burst. After that, there are DL data burst. The UL sub-frame is contained by: the ranging sub-channel is allocated for perform closed-loop time, frequency, and power adjustment as well as bandwidth requests. The first initial ranging transmission shall be used by the mobile station to synchronize with the system. Following that, there are UL data burst [4].

1.3. DVB-Handheld (DVB-H)

At the beginning of the nineties, everyone had his own personal telephone and at the end of nineties, it was used just in most of cases for telephoning or sending and receiving short messages. With the advance of the technology, people wanted to be able to send data and receive via mobile telephone, i.e. check e-mail database for keeping oneself update. Today, mobile phones are no longer telephones but can be used as cameras or as games consoles or organizers, becoming multimedia terminals. Networks operators and manufacturers are continuously searching for more new applications.

Mobile radio networks are networks in which bi-directional connections are possible at relatively low data rates. Broadcasting networks are unidirectional networks in which contents are distributed point to multipoint at relatively high data rates. DVB-H attempts to combine the advantages of broadcast networks and mobile radio networks systems, combining the bi-directionality of mobile radio networks at relatively low data rates with the unidirectionality of broadcast networks at relatively high date rates for transmit digital television to handheld receivers. The downstream from the mobile radio network (GSM/GPRS, UMTS) is sent onto broadcasting network. But if it depends on the traffic volume, when just there is a single subscriber requests will be sent via the technology that is using. If there are a large number of subscribers request the same service at approximately the same time, the communication will be point to multipoint via the broadcast network.
The DVB-H is defined on the existing DVB-T standard for fixed of digital television. The essential parameters of DVB-H correspond to those of the DVB-T standard. Handheld

terminals require some specific features in addition to DVB-T transmission system that has proven its features to serve fixed, portable and mobile terminals. These terminals reduce the average power consumption, the transmission system offer the possibility to power off the receiver in some parts of the reception. Moreover, the transmission systems offer flexibility and scalability to allow different signal receptions of DVB-H, these signals should adapt to different receiver's environment.

The video and audio streams are carried into transport stream using DVB Multiprotocol Encapsulation (MPE) transported in UDP [6]. These datagrams contain port address of the destination and are encapsulated into the payload part of IP packets with their address accordingly. The IP packets are packed in DSM-CC sections which are divided into many MPEG-2 transport streams. As transport stream uses MPEG-2, this DVB baseband signal is the input signal for a DVB-H modulator.

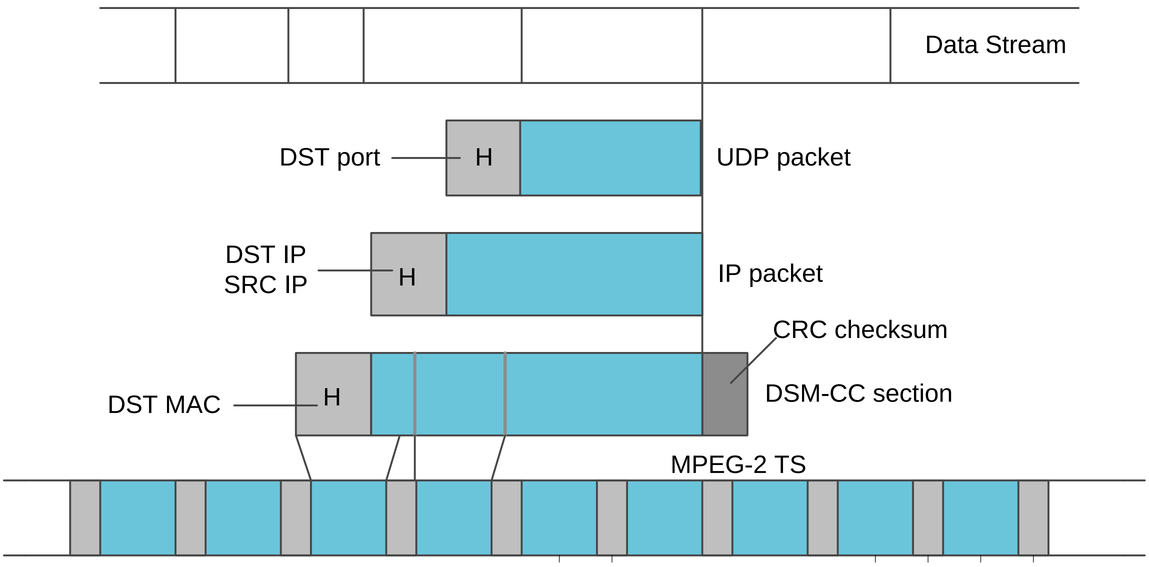


Figure 15. Multiprotocol Encapsulation (MPE)

1.3.1. DVB-H Physical layer

The physical layer of DVB-T has been modified adding extensions. For signaling, two bits have been added in Transmitter Parameter Signaling (TPS) to indicate presence service of DVB-H and also in a cell identifier is supported to enhance and speed up signal scan and frequency handover on receivers. Furthermore, a new mode orthogonal frequency division multiplexing (OFDM) called 4K is added to 2K and 8K, both present in DVB-T. This mode contributes flexibility for the network design. 4K mode is suitable for trading off mobility and single frequency (SFN) cell size, and it allows a single antenna reception in medium SFNs at very high speed. It is optional and complements 2K and 8K modes. Another extension deployed for the mobile standard is a new way of using the symbol interleavers has been designed for improve the robustness in mobile environment and impulse noise conditions. Cell identifier and signaling are mandatory and other technical features could work at the same time.

1.3.2. DVB-H Link layer

In this layer the main additional elements that are modified from DVB-T are time slicing that is obligatory implement and additional error control for data transmission, forward error correction (FEC) coding, and this element is not mandatory. Time slicing reduces the average power consumption in the receiver obtaining a save around 90 %. Also it enables a seamless handover when the user changes the position in order to enter a new coverage cell. The error control for multiprotocol encapsulated data (MPE-FEC) gives an improvement in carrier-to-noise (C/N) performance and Doppler in mobile channels; furthermore, also improves tolerance to impulse interference. Both time slicing and MPE-FEC technology elements, as they are implemented on the link layer so these do not affect the DVB-T physical layer.

1.3.3. Structure user equipment

The user equipment of DVB-H includes a DVB-H demodulator and DVB-H terminal. In DVB-H demodulator implements a DVB-T demodulator that it could deploy 4K mode, time slicing module and an optional MPE-FEC module. The DVB-T demodulator recovers the MPEG-2 transport stream packets from the received DVB-T RF signal. The signal is offered in three transmission modes: 2K, 4K and 8K with the corresponding Transmitter Parameter Signaling (TPS). The time slicing module decodes the desired service and shut off while is not necessary to receive other services. MPE-FEC provides a forward error correction function that allows the receiver to cope with difficult reception situations [6].

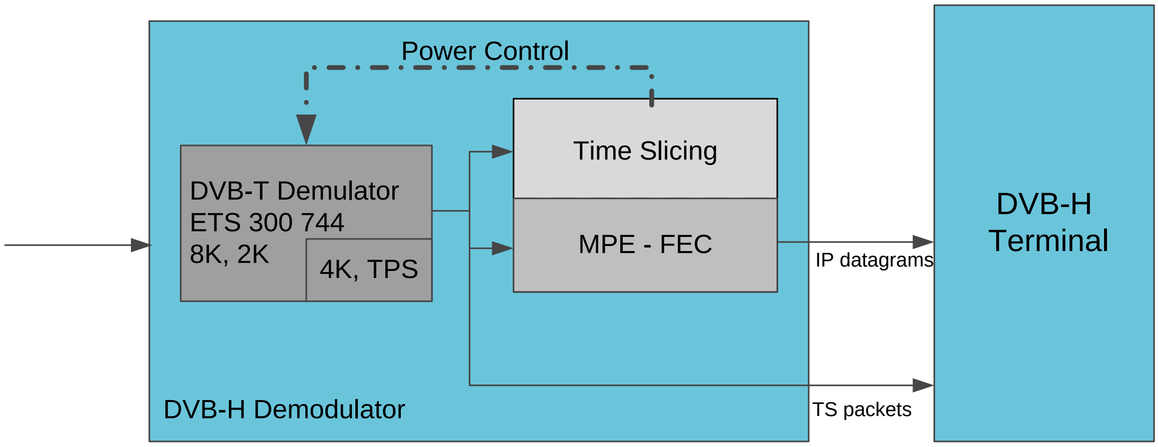


Figure 16. User equipment DVB-H

Using DVB-H for transmission of IP services, the MPEG-2 TV Service is multiplexed with DVB-H data creating the transport stream. This stream is modulated by DVB-T modulator. The handheld terminal decodes IP services, making the inverse process [7].

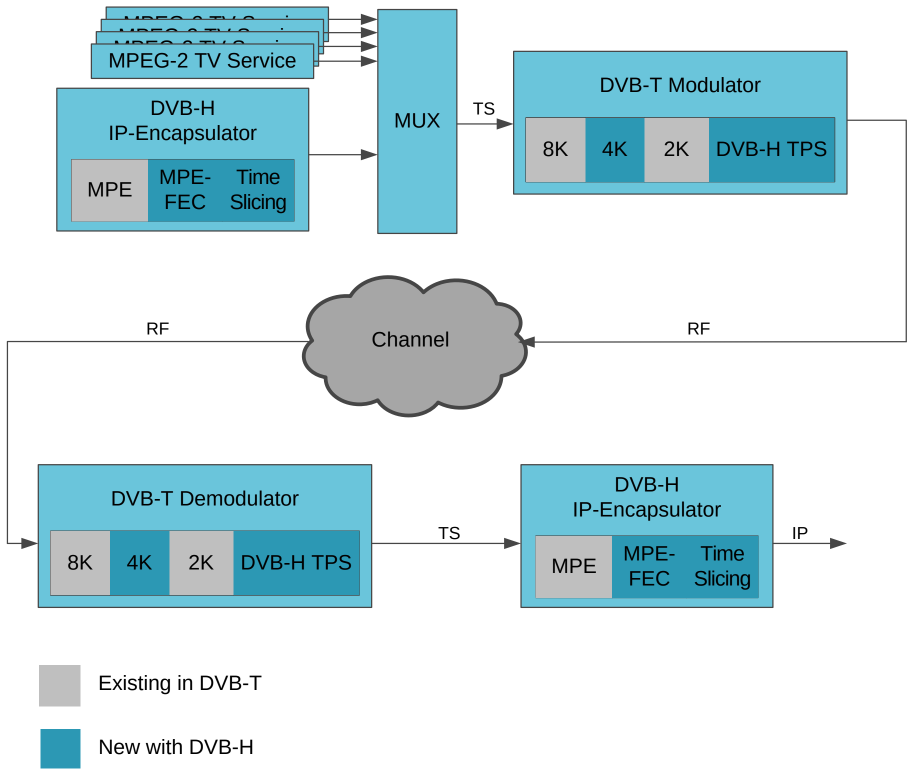


Figure 17. Additions by DVB-H

1.3.4. Handover and roaming in DVB-H networks

Handover in DVB-H is performed and by the terminal devices so they can make accurate handover decisions like to reduce the battery power consumed and execute efficiently handovers behavior including seamless handover. Time slicing can support these features that are required for good communication, when there are off periods the receivers may scan other frequencies in order to find the best potential alternative frequency and to initialize soft handover. In any case may be loss the connectivity and disturb the alternative frequencies. The data streams [8] are sent by using a burst mode instead of a continuous mode how is shown in the next Figure 18.

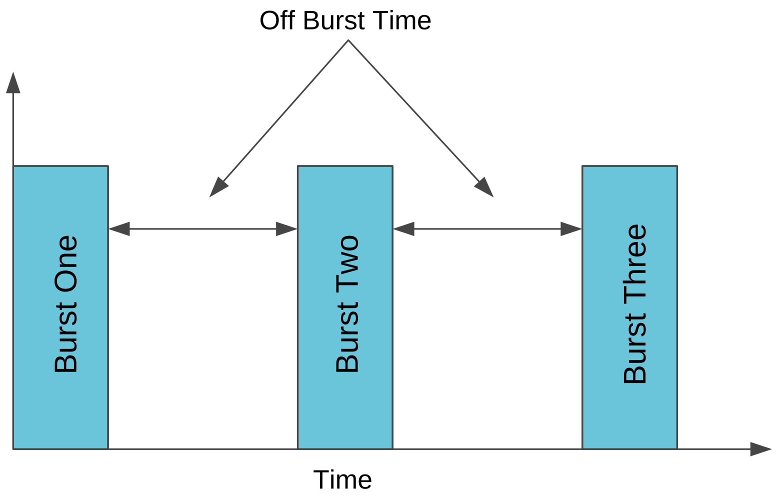


Figure 18. Data Steams

1.3.5. DVB-H Networks

1.3.5.1. The IPDC-System

IP Datacast (IPDC) service is a typical application used in mobile phones that implement DVB-H. A full IPDC system includes various components and elements required to deploy a commercial mobile TV service based on Internet Protocol. It starts producing IP streams like video streams to distribute over the multicast intranet to IP encapsulators, that will create the MPEG-2 transport stream and will be implemented time slicing and MPE-FEC. These streams are by the transmitters over broadcast network. Also this system could include other functions to send over different networks, not just broadcast networks like General

Packet Radio Service (GPRS) or Universal Mobile Telecommunications System (UMTS). The following Figure 19 shows the IPDC-System.

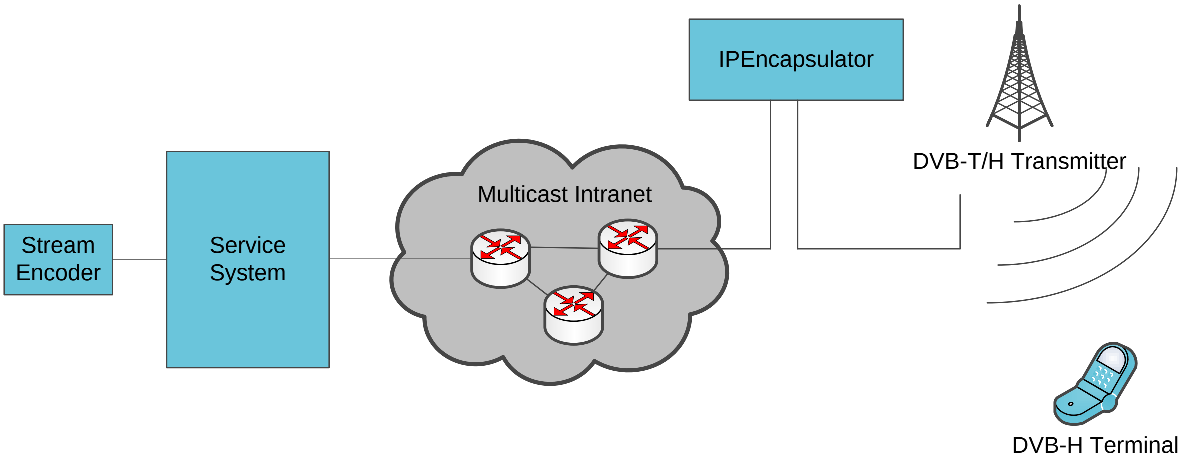


Figure 19. IPDC System.

1.3.5.2. Sharing a network with DVB-T

A shared network with DVB-H and DVB-T is possible. The DVB-T network has to be designed for portable indoor reception. The transmitters require a modification for implement the DVB-H adding signaling bits and cell id into TPS information of the transmitters so in this network, it has to be implemented the components that are required in DVB-H as IP encapsulator (MPE) and time slicing. Also to share the network with DVB-T is to use the DVB-T hierarchical modulation. In this case, the DVB-H IP services will have their independent streams inputs in the terrestrial transmitters. The DVB-H services will use different priorities in normal digital TV services.

2. Vertical handovers

2.1. Introduction

The integration of internet with mobile data networks has enabled mechanisms to appear seamless mobility to the users. These users move across heterogeneous access networks perform vertical handovers. The access technology is changing because while the users are moving their communications are connected to different networks. The main aim is to maintain up the service although the characteristic network varies. Horizontal handover is referred to the mobility within the same access technology. The users change the position so the characteristics in these network no change. By this way, horizontal handover and vertical handover have different requirements and mechanisms to support handover. For example, usage of multiple network interfaces, multiple IP addresses, QoS parameters or different network connections showed in the next Figure 20 [10].

	Horizontal Handover	**Vertical Handover**
Access technology	Single technology	Heterogeneous technology
Network interface	Single interface	Multiple interface
Address IP	Single address	Multiple connections
QoS parameter	Single value	Multiple values
Network connection	Single connection	Multiple connection

Figure 20. Capabilities in horizontal/vertical handover

2.2. Deployment Scenarios

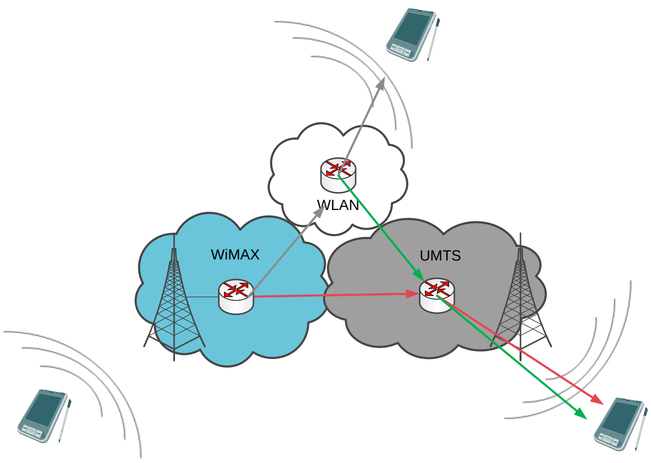


Figure 21. Heterogeneous Network

2.2.1. WiMAX and WLAN

2.2.1.1. Description

This scenario implements a handover procedure that can be executed when a mobile station moves from the coverage of a WiMAX network to coverage of a WLAN network or from WLAN network to WiMAX network. Both networks are using two ways transmission and each network provides different coverage by the respective base station. When the base stations of WLAN and WiMAX networks are overlapped, the mobile terminal is allowed to move from one network to the other obtaining seamless handover without losing connectivity.

WLAN access point provides hot spot access to mobile users for a better throughput in WiMAX network so WLAN can be considered as hot spot coverage for network that provides large radio coverage as WiMAX network. On the other hand, handover between WLAN to WiMAX, due to small coverage area of WLAN, needs to do it as soon as possible to avoid loss of connection.

2.2.1.2. Features

Handover to WLAN may be produced if a better WLAN radio condition is detected. After handover to WLAN the mobile station enters into a semi-idle mode in WiMAX network. This status means that idle is over the 802.16 coverage with no radio resource is assigned and all connection identifier are released except the basic connection identifier. When mobile station does handover back to the WiMAX network, there is not full network entry, because some parameters have not changed.

WiMAX network is normally always available so there is enough time for the mobile station to associate and authenticate the WLAN before breaking the WiMAX connection. When the WLAN connection is completed, the mobile station can disconnect from the WiMAX network. During this process, WiMAX connections are kept alive. After WLAN connection is successfully established, no 802.16 radio resource is assigned to the mobile station except periodical location update request, in order to know location of the device if it is wanted to make handover back.

2.3. The IEEE 802.21 standard

2.3.1. Introduction

Integration of different network to support access allows to create a wide network heterogeneous, this fact increases the capacity and the coverage. The end user can use like a unique network performing seamless handovers between these networks. The networks that provide access are developed by the 3GPP consortium like UMTS and both wired and wireless media in the IEEE 802 family of standards.

The IEEE 802.21 standard provides to the end users to support handovers between heterogeneous networks. There is an inter-technology handovers when is produced change of characteristics transmissions that means connect to other access network. In the case of wire users, the handovers could occur when one network can provide more features than others. The services that are developed by the heterogeneous networks in a handover execution should not be interrupted.

2.3.2. Media Independent Handover Function (MIHF)

This standard supports exchange information available at the mobile terminal and the network infrastructure. There is cooperation between these entities making decisions for enable a successful handover. The standard enables functions within the protocol stacks of the network elements and creates a new entity called the Media Independent Handover Function (MIHF). It is a logical entity that helps and facilitates handovers decisions. This entity just has implication on the mobile terminal or on the network. Also the MIHF receives and transmits information the configuration and status of access networks. The information could be originated by mobile terminal or networks elements at different layers of the protocol stack.

This new layer hides the specificities of different link layers and provides several services that are used by MIH Users for make a handover. Also a Media Independent Handover Service Access Point (MIH_SAP) and associated primitives, that help the MIHF collect link information and control link behavior during handovers, are defined to offer the services to MIH Users. There are three services to detect, prepare and execute a vertical handover.

2.3.3. Media Independent Handover Function (MIHF) Services

The services enhance handovers among heterogeneous access networks providing link layer intelligence for detect the need to make a handover, determinate the best handover and change the candidate link so services facilitate the mobility management and handover process between heterogeneous access links [10].

2.3.3.1. Media Independent Event Service (MIES)

This service detects changes or predicts state changes like characteristics, status and quality in physic layer from local and remote interfaces. Also is used to indicate management actions or command status.

When a handover is initiated, there are some events relevant originated in MAC, PHY or MIHF at the mobile network or network entity. These events are notifications generated asynchronously so all agents that want to receive events need to subscribe to particular events. There are two events categories, Link Events and MIH Events. Events that are originated form MIHF and terminated at the MIHF are Link Events. Entities generating these events to various networks are not limited with only one.

MIH events are originated within the MIHF or they are Link Events that are propagated by the MIHF to the MIH Users. The following Figure 22 shows the different Link events and MIH event:

Link or MIH event name	Description
Detected	New access network has been detected. It is typically generated on the mobile node when an access network is detected.
Up	Connection with lower layers and link is ready for use.
Down	Connection with lower layers and link is broken.
Parameters_Report	Link parameters have crossed a specified threshold and need to be reported.
Going_Down	Link connections are degrading and connection loss is imminent.
Handover_Imminent	Handover is imminent.
Handover_Complete	Link handover has been completed.
PDU_Transmit_Status	Indicate transmission status of a PDU.

Figure 22. Link and MIH event

Events can be originated local or remote; a local event across different layers inside the local protocol stack of an MIH entity, while a remote event across the network medium from one MIH entity to another MIH entity. All the connections between remote entities are provided by MIHF. The link event is always local event because it is originated from local lower layer to the local MIHF. MIH Events are local or remote. A remote MIH Event could traverse the medium from a remote MIHF to the local MIHF originated by lower layers and then forwarded to the local MIH Users that have subscribed to this remote event.

The determination to make a handover between intra-technology and inter-technology is not just a decision when a link event occurs, it is also based on variety of other factors. The network selection entity always tries to maintain the current connection giving priority to intra-technology handovers and later, if it is not possible to inter-technology handovers.

2.3.3.2. Media Independent Command Service (MICS)

The use in this service is to help MIH Users to determinate the best handover obtaining network information taking control link status involved in the handover. MIH Users send commands to determinate the status of the links and also it can control the devices involved in the network.

There are several parameters that could be changing when mobile station is moving so that information is provided by MICS is dynamic and includes signal strength and link speed. If the mobile station is changing its position, MIH Users use commands to configure, control and retrieve information in order to do everything needed from lower layers including MAC, PHY and Radio Resource Management. The command could be classified into two categories: MIH Commands and Link Commands. MIH Commands are originated form MIH Users to MIHF and Link Commands from MIHF and directed to the lower layers.

MIH commands request can cause events indications to be generated. These requests indicate a future state change in one of the link layers in the local node. All MIH users that be subscribed, they will be notified about these changes link and it allows to be better prepared to take appropriate action.

Link Commands control the behavior of the lower layers and just are local; however, MIH commands can be local or remote. The communication between two entities is by MIHF. The remote MIH Command could be direct to remote's MIH Users as MIH Indication or to lower layer like Link Command. The next Figure 23 shows the different commands could be generated:

Link command	**Comments**
Link_Capability_Discover	Query and discover the list of available link layer events and link layer commands.
Link_Event_Subscribe	Subscribe events from a link.
Link_Event_Unsubscribe	Unsubscribe events from a link

Link_Configure_Thresholds	Configure thresholds for Link Parameters Report event.
Link_Get_Parameters	Get parameters measured by the active link.
Link_Action	Request an action on a link layer connection
MIH command	Comments
MIH_Link_Get_Parameters	Get status of a link.
MIH_Link_Confugure_Thresholds	Configure link parameter thresholds.
MIH_Link_Actions	Control the behavior of a set of links.
MIH_Net_HO_Candidate_Query	Network initiates handover and sends a list of suggested networks and associated elements network.
MIH_MN_HO_Candidate_Query	Command used by mobile node to query and obtain handovers information about possible candidate networks.
MIH_N2N_HO_Query_Resources	Allow for resource query by the serving MIHF entity to the target MIHF entity.
MIH_MN_HO_Commit	Mobile network obtain information of the decided target network.
MIH_Net_HO_Commit	Network notifies to the mobile network of the decided target network information.
MIH_N2N_HO_Commit	A serving network informs a target network that a mobile network is going to move forward that network.
MIH_MN_HO_Complete	Notification from MIHF of the mobile network to the target or source MIHF indicating the status of handover completion.
MIH_N2N_HO_Complete	Notification from source or target MIHF to the other MIHF indicating the status of the handover completion.

Figure 23. Link commands and MIH command in MICS

2.3.3.3. Media Independent Information Services (MIIS)

With this service, the device can obtain details and characteristics of neighboring network, providing to higher layers stack taking control to lower layers. User and network operator can obtain an optimum initial network selection or attachment. The objective is to acquire a global view on all the heterogeneous networks near mobile network to facilitate seamless attaching to these networks. This service supports different types of information depending on the type of mobility that are required for performing handovers, for example obtaining information about lower layers like take a view of neighbor map or another link layer parameters. Different candidate networks could change information between mobile user and service provider.

The information that service could provide is to know the availability of access networks in a determined geographical area. Mobile node knows the range of networks that are around. Also it can be provided link layer information parameters that help mobile nodes to select the better access network in a heterogeneous medium, when it is needed parameters like QoS or security. In order to make an optimal handover, is needed to know radio parameters about networks entities, i.e. supporting channels, it will not be necessary scan working channels.

The information is enclosed in various containers called in Information Elements (IE) that are classified into three groups: general information and access network specific information that give a general overview of different networks, the second group is the several Points of Attachment are available in the networks and the last group is made up with other information that access network specific, service specific or vendor specific are offered.

The next Figure 24 shows the interaction of these services used by MIH Users and provided for MIH_SAP in mobile terminal or network entity.

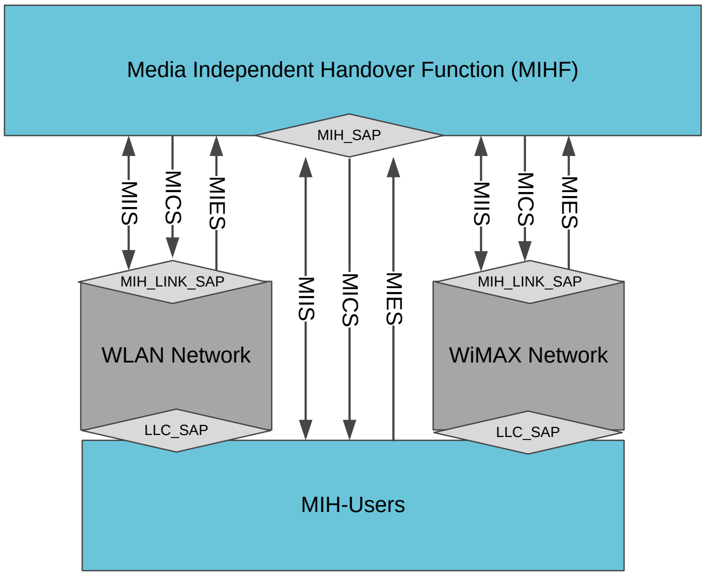


Figure 24. IEEE 802.21 deployment

2.3.4. MIHF communication model

There are exchanges MIH messages between network side MIHF and mobile node MIHF. For each MIH network entity includes an MIH Point of Service (PoS) that is connected to mobile node. A MIH network entity not just has one MIH PoS, it may include multiple that may provide different MIH services for several mobile nodes. When a MIHF communicates directly with mobile terminal in any network, entity becomes a MIH PoS. The MIH PoS for a particular mobile node cannot be a MIH network entity because has not a direct connection. One MIH PoS may be connected to different MIH mobile node. In the MIHF communication model can be several roles like the following Figure 25 shows:

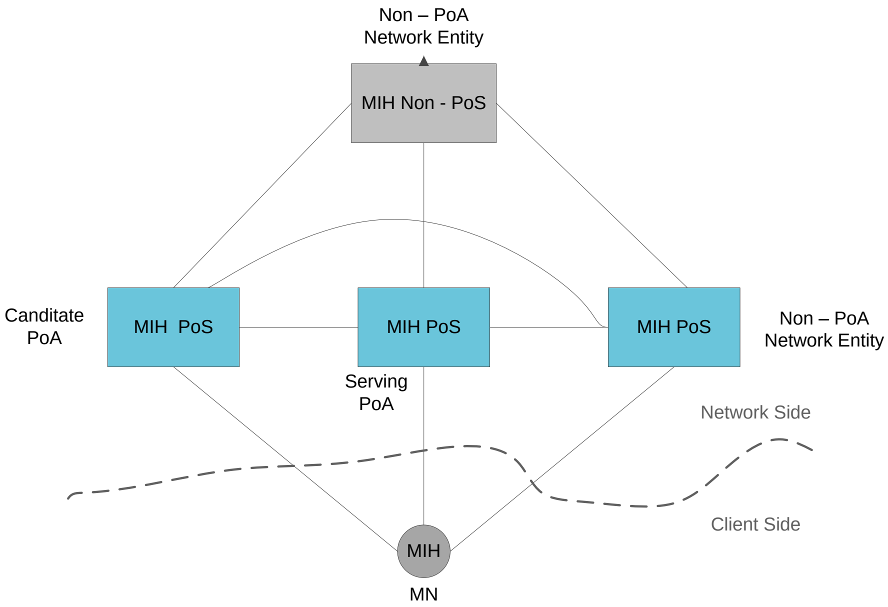


Figure 25. MIHF communication model

On mobile node, there is implemented MIHF. One of network entity elements there is implemented an MIH PoS, serving PoA (Point of Attachment) of the mobile node. This element takes part of end node in network entity and for mobile node is also the other endpoint. Another PoS on the network entity that is offered like PoA for the mobile node. There is other MIH in another network entity that is not a PoA for the mobile node. Finally, it exist a MIH non-PoS on a network entity that does not include a PoA for the mobile node.

2.3.5. Service access points

The MIHF uses Service Access Points (SAPs) for exchange information. Each SAP consists of a set of service primitives. SAPs provide services to upper layers that these layers are subscribed with the MIHF as users to receive MIHF events and also link layer events that are originated at layers below the MIHF. The MIH Users send commands to MIHF using the service primitives that are provided by MIH_SAP. During the handover there are commands generated by the MIHF to control the physical and medium access control layers that form part of the specific MAC/PHY SAPs. The MIH_LINK_SAP specifies a communication between the MIHF and lower layers of protocol stacks of technologies like IEEE 802.3, IEEE 802.11, IEEE802.16 and UMTS. The Network Management System (NMS) configures parameters in the MIHF so MIH_NMS_SAP allows it. For exchange information between local and remote MIHFs uses the MIH_NET_SAP. The next Figure 26 shows MIHF related SAPs:

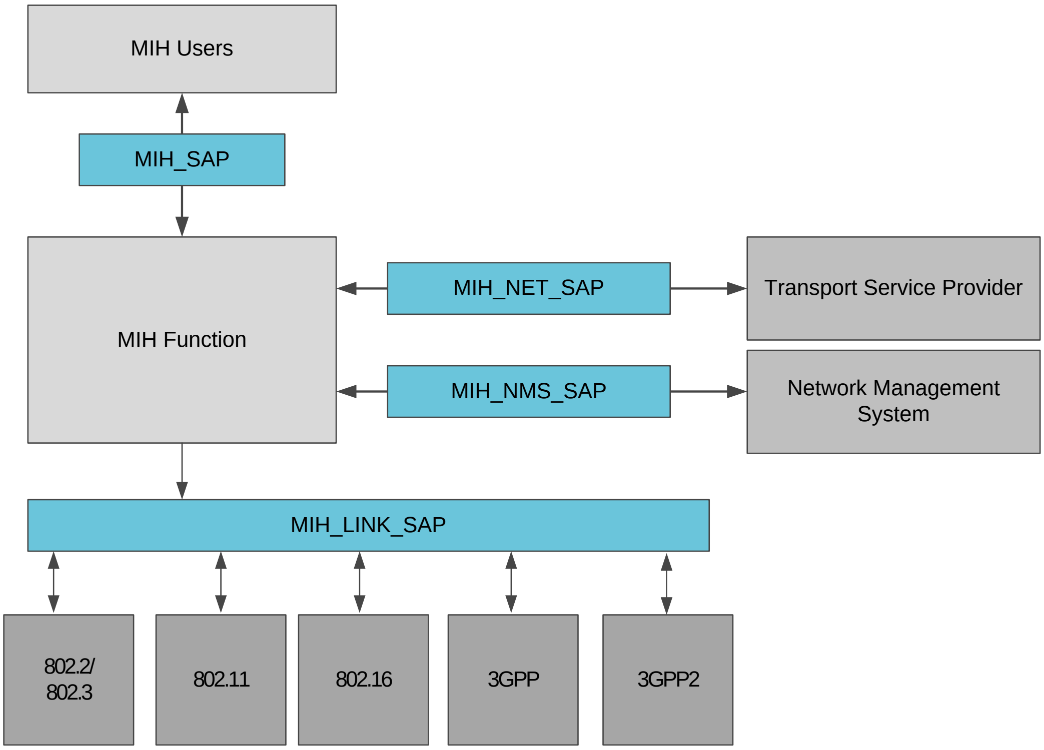


Figure 26. Relationship between different MIHF SAPs

2.3.6. Media independent handover protocol

The Media Independent Handover protocol defines the messages that are exchanged among remote and local MIHF. This protocol takes care of encapsulation in MIH frames and sends over the physical link. The form of encapsulation depends on the transmission way used it. The messages are sent with TLV and the standard defines some type value encodings for the TLV including several fields: IP Renewal Flag, Link Down Reason Code, Confidence Level, Handover Mode, and Link Action.

2.3.7. Integration Broadcast technologies and the IEEE 802.21 standard

IEEE 802.21 standard is not supported by technologies that are unidirectional communications. In order to provide bidirectional channels in technologies that are one channel by nature, should implement mechanisms for simulation bidirectional link on unidirectional systems. One mechanism that allows to create a bidirectional link over unidirectional technologies is the UniDirectional Link Routing.

Combining the IEEE 802.21 and the UniDirectional Link Routing is achieved seamless handover in heterogeneous networks access.

3. UniDirectional Link Routing

3.1. Introduction

In order to emulate full bidirectional channel between nodes that are connect by unidirectional links are used UniDirectional Link Routing mechanism [11]. This mechanism forms part of Request For Comments RFC3077 and describes a link-layer tunneling, that for Internet routing and upper later protocols send datagrams seem the links are all connected bidirectional so the technologies that are based on unidirectional links like broadcast services may provide a return way with the tunnel created by this mechanism.

The transmitters send the packets over the unidirectional link that is connected to the receivers. This mechanism could implement for any topology with any number of receivers and one or more transmitters. The receiver has several interfaces that have just receive interface and one or more bidirectional communication interfaces. The transmitters use to have several interfaces among them unidirectional and bidirectional. In the bidirectional interfaces of the nodes are created the tunnels over Internet connection, IP infrastructure.

To maintain operative the tunnels, it is needed a protocol for to achieve this purpose. Dynamic Tunnel Configuration Protocol (DTCP) realizes set up and update the tunnels, also to have connectivity among feeds and receivers, avoiding all the time losses connection between end-points.

Using UDLR some problems arise due to it is creating an emulated bidirectional communication when ,in fact, it is unidirectional communication. Long round trip time, address resolution, routing protocols and security are these problems

3.2. Tunnel operation

Tunneling mechanism operates in the link layer under the network layer that has no knowledge how it is working on the underlying layers, just knows that it is working as bidirectional. To set up tunnel end-points for work as bidirectional in a unidirectional communication, they are configured with different way because one transmission ways is broadcast and the other is unicast that is the return channel so have to be configured adapting to these features.

3.2.1. Receiver

Receivers are end-points in the unidirectional communication subscribed to broadcast services that they send by the link. By nature the communication have not chance that receivers send back information, therefore it is needed to create a return path for to be communicated with source transmitter.

When the receiver wants to send information over the tunnel, this information is trade with different steps because it cannot send directly to the transmitter, it is necessary to create a process to be able to send the datagrams to the tunnel. This process permits forward datagrams by the created tunnel running generally over Internet network. First of all, the datagram is encapsulated within a MAC header with information about unidirectional link and then, it is processed by tunneling mechanism. In this process, the corresponding packet is encapsulated within IP header with address corresponded with bidirectional link. The IP address destination is end-point address. It is pictured in the next Figure 27 the steps for where send the information.

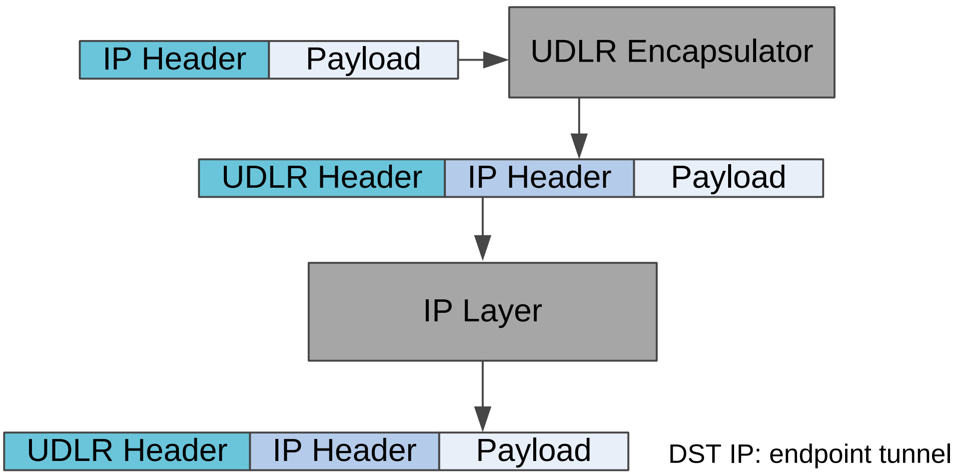


Figure 27. UDLR mechanism in bidirectional link

The packets are delivered to the transmitter that is listening for incoming encapsulated datagrams on their tunnels by the bidirectional interface and it will be decapsulated and delivered to the higher layers. The datagrams are processed like if they were arrived direcly from unidirectional interface, just the way from they have come is different. In all nodes that the datagrams have been processed but any has modified the packet so the original MAC header is intact.

3.2.2. Transmitter

On the opposite channel, the transmitter does not need to send packets by the tunnel the mechanism are very simple. The transmitter just has to send the datagram over the unidirectional link and then the receiver node will receive them. After that, the IP layer will extract the payload and will deliver to the upper layers. Any extra operation is required because this communication follows the direct way. The next Figure 28 shows the process:

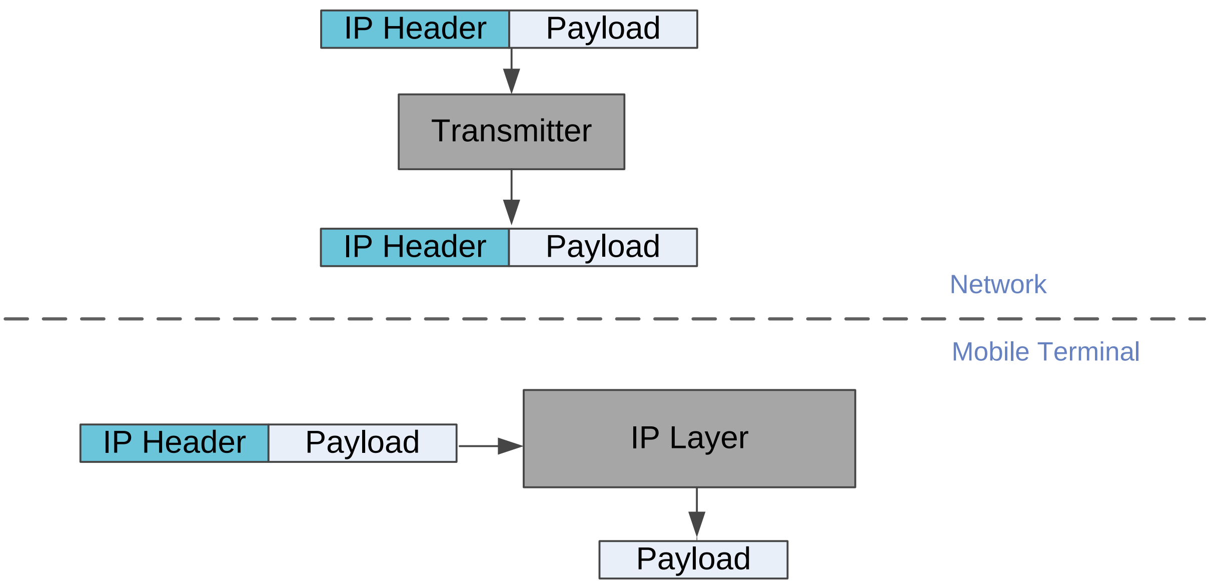


Figure 28. UDLR mechanism unidirectional link

Packets are sent to one receiver or various by using a unicast MAC destination address or a multicast/broadcast destination address so the receivers can filter the input data sent over the unidirectional link without knowing which information contain the packets. On multicast/broadcast mode, transmitters send a copy to all unidirectional links reaching all subscribed receivers.

3.3. Dynamic Tunnel Configuration Protocol (DTCP)

In order to have operative, the tunnels exist a protocol to configure them. The name of this protocol is Dynamic Tunnel Configuration Protocol. It sets up the tunnels and maintains dynamically. The transmitters announce the tunnels that are subscribe over the unidirectional link and the receivers listen these events and maintain list of tunnels end-points. Tunnels are periodically checked and by receivers that maintain an operative list of tunnel end-points when the transmitters announce their tunneling connections.

Tunnels may have to be reconfigured due to a several events that could take place in return path communication. One of these is if a new tunnel end-point is created, that means a new transmitter comes up so wants to send broadcast service traffic, for that reason, every subscribed receiver must create a tunnel to enable bidirectional communication with this new source. Second, all receivers have to know unidirectional channel status, if there is a change in it they should adapt to them. It could be that unidirectional link may be down so receivers should cancel their tunnels. The feeders may not receive any information because bidirectional is broken. Another event can occur, the loss of transmitter therefore, to not create unnecessary traffic the receivers must disable their tunnels because there is not meaning transmitters receive data when they are down.

3.4. Problems with integrating UDLR

Creating an emulated bidirectional communication is not symmetric in terms of delay and bandwidth because the return path between receiver and transmitter is not the same and also is over Internet, some problems emerge.

Routing protocols may run in this topology making forward task in the packets between transmitter and receivers exchanging by bidirectional network. How the connections are set up over Internet and these protocols are working not just for routing protocol messages, data IP traffic too, they can be configured a low metric in order to solve asymmetries characteristics of the communication looking like direct connection.

Other problem that could exist is in satellite communications that sends data in unidirectional link. Delays in this conditions are high so it could give a trouble if some problems as hardware address resolution appears because waiting a time longer more time than necessary the packets in data stream will become lose. Address Resolution Protocol (ARP) that in some case may not work well and the transmitter is waiting response for know mobile node address, the IP stream packets are ready to send cannot be delivered for this reason causing more delay in connection or even loss of data.

Other problem that it should be considered is the security in a network using UDLR. Nodes that have two interfaces can become a unidirectional network receivers and to cause information misuse. Everything starts when DTCP announces its IP address tunnel end-point so unauthorized receivers detect this and provide false routing information over unidirectional link. Therefore, link layer security mechanisms may be implemented or running on top layers to prevent it.

4. Simulation Tools. NS2

4.1. Description

Network Simulator is a simulator created to model IP networks. On the simulation two elements take part, one of them is the structure and the other is packets traffic that has it so it creates a diagnostic that shows the behavior of certain feature.

It is possible simulate common environments that usually are working over wired and local or satellite wireless networks implementing transport protocols such as TCP and UDP, traffic protocols like FTP, Telnet, HTTP, CBR and VBR. It uses several queue mechanisms in router such us DropTail, RED, etc [12].

The software is open source so it is not finished and continues development for improving it. The simulator is object-oriented and programmed in C++. It supports OTcl in order to users create objects and parallelly it is created an object in the editors. Network Simulator uses two kinds of languages because the simulator implements two different functions. C++ is used for efficiently work with parameters, packets, headers and algorithms that is important to have a fast processed, to achieve with this type of programming language. On the other hand, in order to study networks varying parameters or scenarios configuring is not required so much execution time so OTcl is suitable in this case.

4.2. Operation

The simulation starts with Otcl script run. It is written the reference code of simulation. Users have to create a scenario that will be simulated and they will just give this input to the simulator, then, it will be created a file that could be a little bit difficult to read or analyze. However, a specific application shows a graph to learn what it means.

This Figure 29 shows the general steps for run a simulation with Network Simulation.

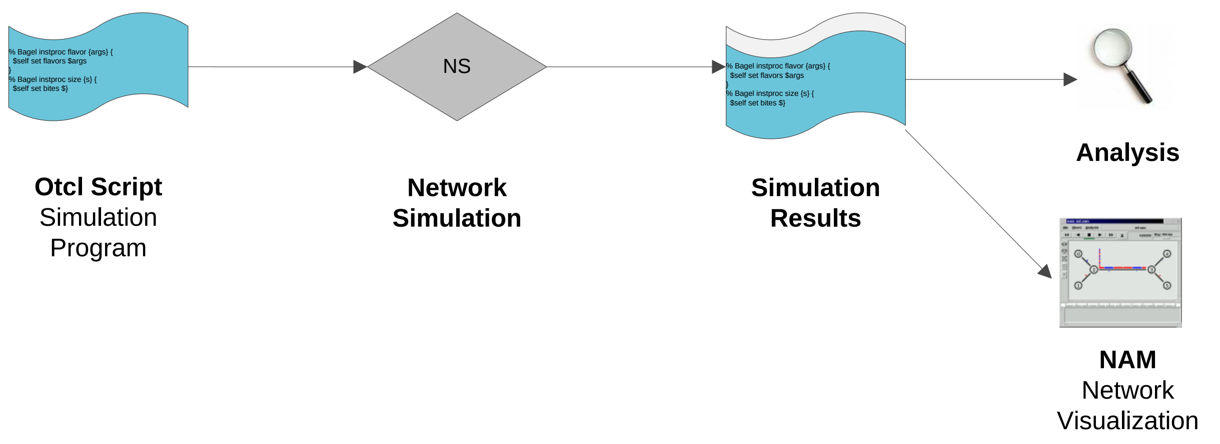


Figure 29. Network Simulator

The script runs several components from network, for example, control the events and charge functions needed for the simulation, scheduling when it has to start o stop packet traffic.

In this script, it is defined the physic network configuration such as nodes, connections between nodes, also the protocols will be used in the connections and definitions specific using connections about applications. The script is a file with extension “*.tcl”. When it is executed, it creates an analysis output. This output is formed for two files, it is created by “*.nam” and “*.tr” files. It shows a complete description about simulation. There is a parallel application for graph the results named nam. It lets to have a better intuition about the results; it could give an exact evaluation. There is pictured the process for execute a simulation in the next Figure 30:

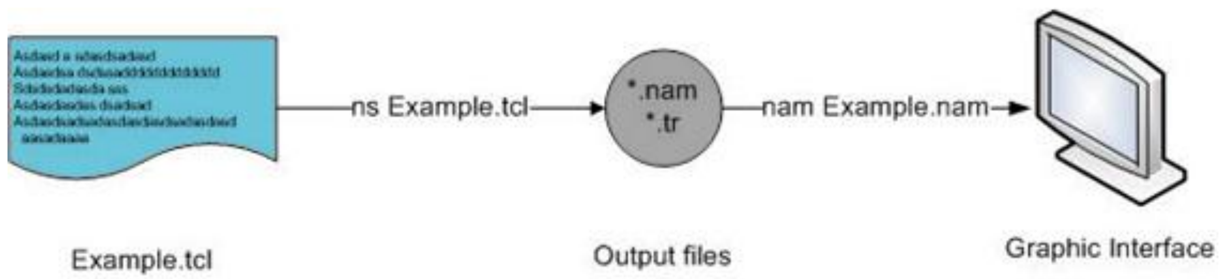


Figure 30. Executing simulation from Example.tcl

To create a scenario, it is necessary to make a script Tcl. Below it shows an example. There is created a scenario with four nodes. Node 0 send FTP traffic over TCP 2 and also node 1 sent CBR traffic over UDP to node 3 crossing node 3.

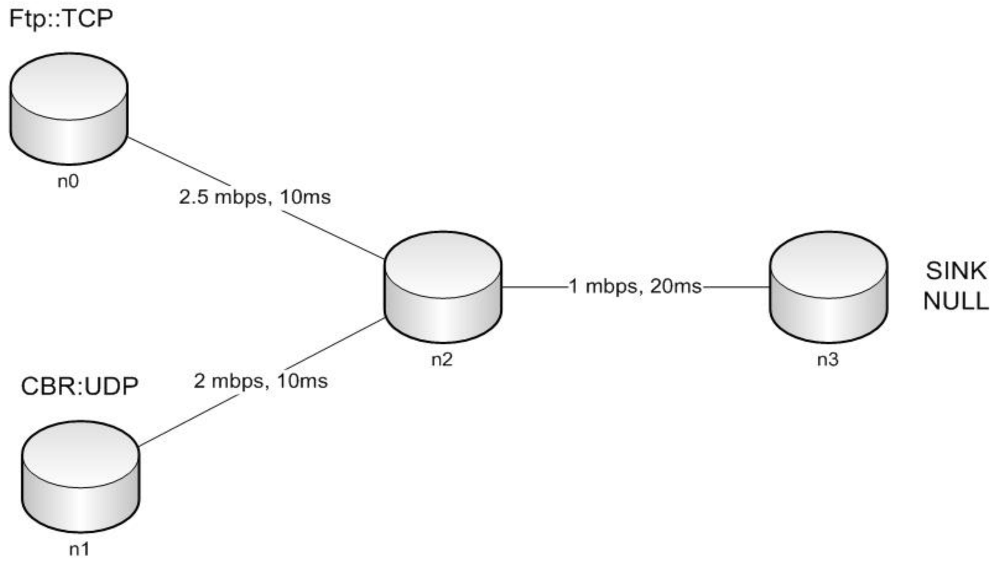


Figure 31. Example diagram network

The script TCL created to simulate this scenario is the following code [13]:

- Define the file where the simulation will be created

```
set ns [new Simulator]
set nf [open out.nam w]
set tf [open out.tr w]
proc finish {} {
global ns nf tf

$ns flush-trace #
close $nf # Close *.tr file
close $tf # Close *.tr file
exec nam out.nam & # Run *.nam file
exit 0
}
```

- Configuration the scenario

```
set n0 [$ns node]
set n1 [$ns node]
set n2 [$ns node]
set n3 [$ns node]

$ns duplex-link $n0 $n2 2.5Mb 10ms DropTail #BW: 2.5Mbps; Delay: 10ms.
$ns duplex-link $n1 $n2 2Mb 10ms DropTail #BW: 2Mbps; Delay: 10ms.
$ns duplex-link $n2 $n3 1Mb 20ms DropTail #BW: 1Mbps; Delay: 10ms.
$ns queue-limit $n2 $n3 10
```

- Set up the nodes with agents

```
set tcp [new Agent/TCP]
$ns attach-agent $n0 $tcp #Attach agent on n0
set sink [new Agent/TCPSink]

$ns attach-agent $n3 $sink #Attach agent on n3
$ns connect $tcp $sink #Created connection between n0 & n3
set ftp [new Application/FTP]
$ftp attach-agent $tcp
$ftp set type_ FTP

set udp [new Agent/UDP]
$ns attach-agent $n1 $udp #Attach agent on n1

set null [new Agent/Null]
$ns attach-agent $n3 $null
$ns connect $udp $null #Connection UDP-NULL agent
$udp set fid_ 2

set cbr [new Application/Traffic/CBR]
$cbr attach-agent $udp
```

```
$cbr set type_ CBR
$cbr set packet_size_ 1000 # Maximun size of packet
$cbr set rate_ 1mb
$cbr set random_ false
```

- Start the simulation

```
$ns at 0.1 "$cbr start"
$ns at 0.5 "$ftp start"
$ns at 4.5 "$ftp stop"
$ns at 5.0 "$cbr stop"
$ns run
```

4.3. Trace Analysis

In script file, it is specified create the file "*.tr" that when TCL script is run generate as output and it will be used for analyze the simulation. In the next Figure 32, it is shown a trace format and example trace from "tr" file [14].

event	time	from node	to node	packet type	packet size	flags	fid	source address	destination address	sequence number	packet id.

r	:	receive			
+	:	enqueue	src_addr	:	node.port (2.1)
-	:	dequeue	dst_addr	:	node.port (0.1)
d	:	drop			

+	0.1	0	1	cbr	1000	-------	2	0.0	2.1	0	0
-	0.1	0	1	cbr	1000	-------	2	0.0	2.1	0	0
+	0.1	2	0	cbr	1000	-------	1	2.0	0.1	0	1
-	0.1	2	0	cbr	1000	-------	1	2.0	0.1	0	1
+	0.108	0	1	cbr	1000	-------	2	0.0	2.1	1	2
-	0.108	0	1	cbr	1000	-------	2	0.0	2.1	1	2
+	0.116	2	0	cbr	1000	-------	1	2.0	0.1	1	3
-	0.116	2	0	cbr	1000	-------	1	2.0	0.1	1	3
+	0.116	0	1	cbr	1000	-------	2	0.0	2.1	2	4
-	0.116	0	1	cbr	1000	-------	2	0.0	2.1	2	4
r	0.118	0	1	cbr	1000	-------	2	0.0	2.1	0	0

Figure 32. Trace Analysis

"Tr" file is composed by lines that each line starts with a description of the event, followed by the time that was executed this trace line, from and to which node the event occurred, packet and type size. Flags are showed as "-----" because were not set. The next field is fid (Flow Id) to identifier each input flow. Also it can find source and destiny node port and the sequence packet number with corresponding identifier.

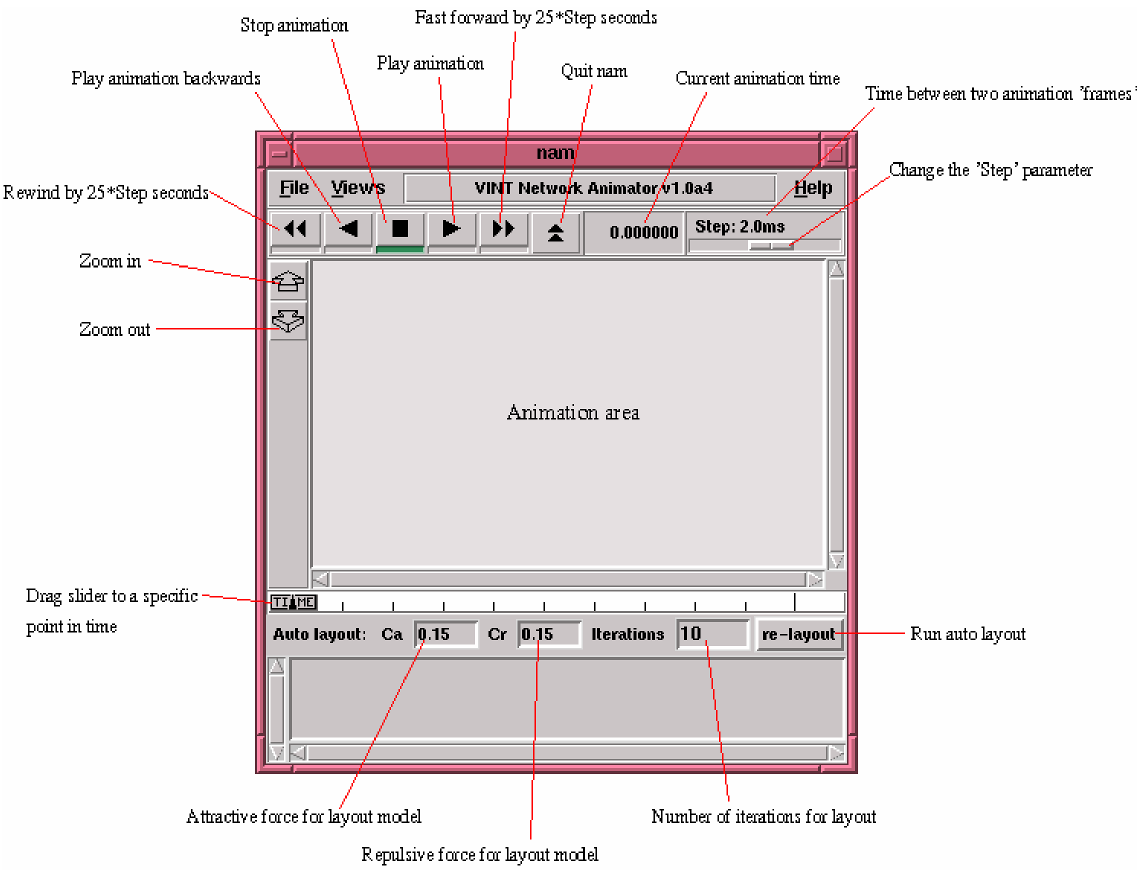
With this information, it is possible to make an exhausted study how the simulation is going. There are applications that can filter the information as user wants like egrep or awk.

Other tool to analyze the simulation is Trace Graph [15]. It is a trace files analyzer for network simulator NS2 trace processing. There is possible take out some information about network simulation and creates graph about different network features.

4.4. Network Animator

Network Animator (Nam) is a tool for animating packet trace data. The trace data is the output file from Network Simulator (NS2). Input files are ".nam" extension created after NS2 execution. In this file, it is explained every events that animation tool has to execute line by line so with nam it is possible easily understand because it is showed step by step what it is happening during the simulation obtaining true assessment in a friendly graphic interface.

In the following Figure 33, it is shown nam appearance:



.

Figure 33. NAM Appearance

The main options of nam tool are:

- Animation Area: In this zone is showed network topology specified in simulation.
- Play/Stop/Forward/Rewind Animation: Are used to start, stop, or change animation step.
- Zoom In/Zoom Out: Increase or decrease simulation area.
- Current Animation Time: It is time passed since simulation started. Maximum time has been specified in simulation script.
- Step: Show simulation speed in milliseconds. Can be changed while simulation is running.
- Edit: Layout are predefined, it is possible to change elements position.

5. Simulations

5.1. Implementation UDLR

In order to create this simulation in NS2 [16] [17] [18] [19] [20] [21], it is implemented several features in the scenario to simulate real behavior of UniDirectional Link Routing. Main idea is to create a similar scenario topology that seems similar as broadcast services, where broadcast signal is sent by unidirectional link and there is a return path to connect with transmitter send the data information over Internet. In the scenario, it is created one unidirectional link and two bidirectional links. The unidirectional link that represents the broadcast link is forced to work in just one direction. Under this condition it is mandatory to send packets in one way. There are three nodes (node0, node1 and node2) created and connected by ring topology. Each node has assigned an IP address as X.X.X in order to understand easier which nodes are involved in the process. Node0 is connected with node1 with bidirectional link. Between node1 and node2, there is other bidirectional link. These links emulate the tunnel created by UDLR. Finally, a unidirectional link connects node2 and node0 emulating the broadcast communication. Creating this configuration allows people to see how the packets are routing by the different links looking the behavior if it would be a real UDLR mechanism. Scenario is created with network simulator application (NS2). Tunnel mechanism is simulated by blue arrows between node0 and node2 and green arrow the unidirectional link on next Figure 34 shows:

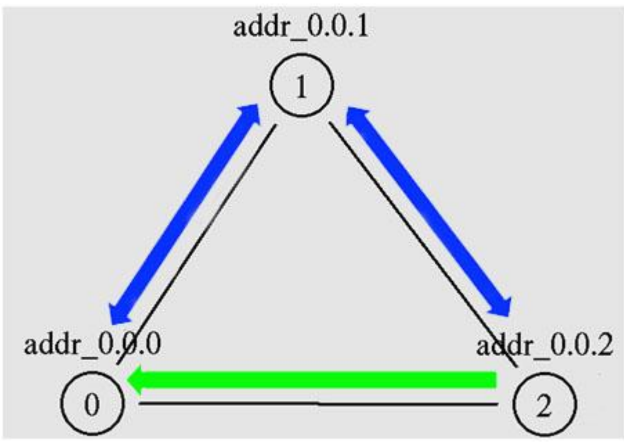


Figure 34. Scenario UDLR

In some nodes, it is configured a traffic that has a static amount of bandwidth and is possible to observe constant scenario´s performance. The traffic is CBR (Constant Bit Rate) provided by an agent installed in the node. The nodes on is installed CBR are in 0 and 2. Traffic is configured with 1 Kb packet size and 1 Mbps rate. And links with 10 Mbps bandwidth and 10 ms delay. The traffic goes over TCP traffic because it is necessary to see acknowledge packets way. These packets are 40 bytes and they are delivered to the agents who created CBR traffic. When a node receives a packet that has its IP address, it will generate an acknowledgment packet and will be delivered to the source taking shorter path.

In the next Figure 35, there is routing table that was prompt by the application showing how the packets are forwarded:

```
Dumping Routing Table: Next Hop Information
        0       1       2
0       --      1       1
1       0       --      2
2       0       1       --
```

Figure 35. Routing Table

For example, if the packet that is in node0 should go to node2, the next hop is 1 (taking bidirectional link), but if the packets is in node2 and should go to node0, the packet takes the node1 for next hop. The packets always take the short way to go to destination.

The next Figure 36 shows an acknowledgment packet that is generated by node0 and must be delivered to node2. How it is not possible take node0 to node2 direction because is not bidirectional link, the packet must not go by the link that is from node0 to node2 so it should take the way node0, then node1 and finally node2, simulating the UDLR mechanism. Otherwise could not be possible to be delivered.

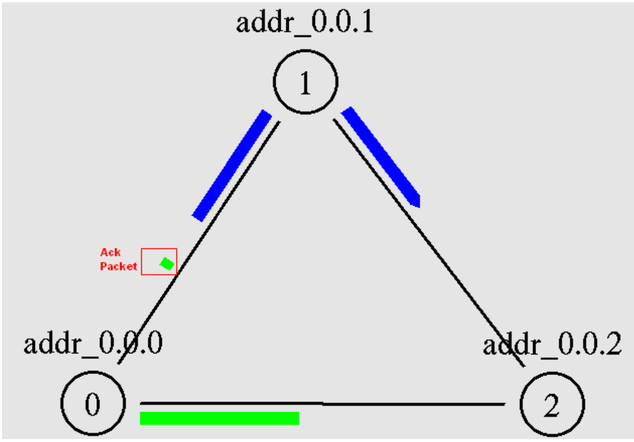


Figure 36. Ack Packet

5.2. UDLR and 802.21 Signaling

In the following simulation, a scenario is created to evaluate the different performance of handovers in heterogeneous access networks. The network provides IEEE 802.11 and IEEE 802.16 technologies. This scenario is developed by Institut für Nachrichtentechnik, TU Braunschweig. There is a mobile terminal that is changing its link access during the movement. Device crosses technologies that are based on different characteristics. Making an easy communications because are not developing with same features, between devices that are using these technologies, is needed work together with IEEE 802.21. It means device does not know in which technology are implemented because just is contact 802.21. To provide broadcast services in this scenario is also needed UDLR mechanism to have bidirectional connection in the scenario. When simulation starts, the mobile terminal is not connected to any network. After a while, it is connected to IEEE 802.11 hotspot and later to another IEEE 802.11 coverage passing through IEEE 802.16 network. In this moment it makes two handovers through three different technologies's coverage area. Finally, it will be returned to the first point making handovers by the same networks. In the following Figure 37, there is the scenario described.

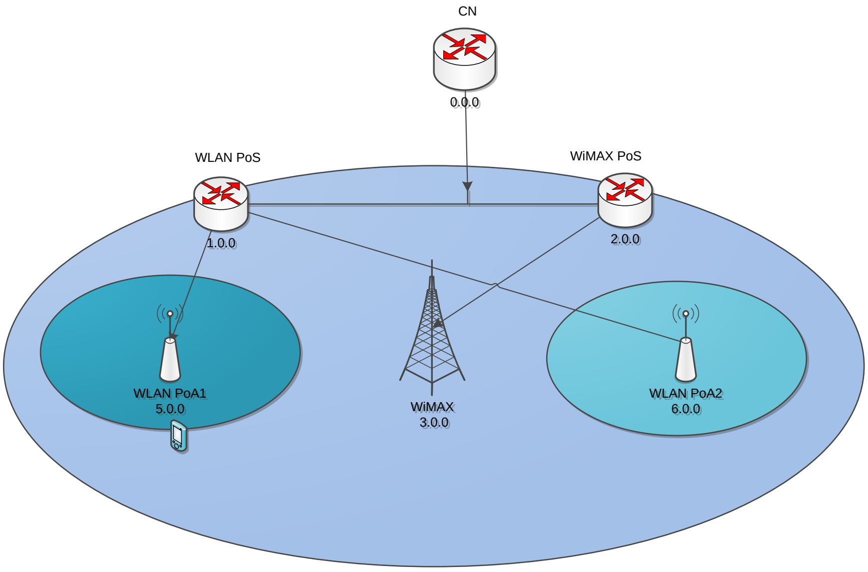


Figure 37. Scenario 802.21 Signalling

If there are implemented broadcast services in this scenario, in order to execute a handover, some packets could not be reached by the original way because of links whose original were bidirectional so applying these services will be unidirectional. The solution is to be implemented UDLR to deliver the packets to the network entities. In the next Figure 38, there is the tunnel created with grey line and the broadcast traffic is shown by blue line that carries downloaded packets to mobile terminal.

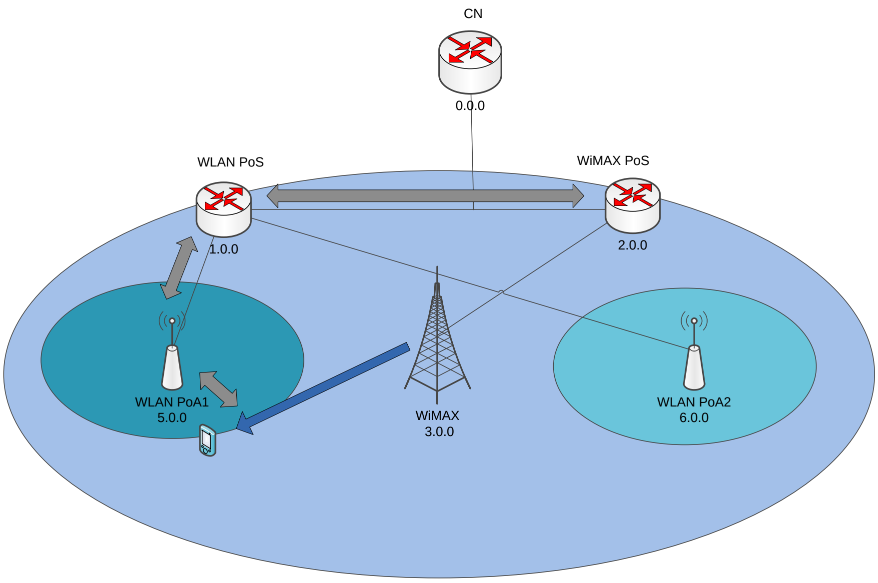


Figure 38. Scenario UDLR & IEEE 802.21 Signalling

For example, in the following picture, there are some codes created by the simulation that it not would be possible if UDLR implementation exists, there is a restriction due to before all links created were bidirectional.

In code generated by the application, some packets will not be reached the original nodes because path that had established previously, now these links are not unidirectional so they can not be delivered by the same way, they should be sent over created tunnel by UDLR mechanism. Therefore, there are two handover packets shown in the next Figure 39 are created by mobile terminal with IP address 3.0.2 and destination address 3.0.0 that is WiMAX access point. These packets would not be able to be sent just in one hop. They should be sent by the tunnel and deliver to corresponding access router. The tunnel is created from the mobile terminal to WiMAX access router crossing IEEE 802.11 technology.

```
create pending request
Created new pending request request tid=2, request:16



At 31.146925 in 3.0.0 MIH Agent received MIH_Handover_initiate.request from remote User
    (packettype: mih    src_nodeaddr: 3.0.2 dst_nodeaddr: 3.0.0)


At 31.146925 in 3.0.0 HandoverMihoAP received MIH_Handover_initiate.indication
    (packettype: mih    src_nodeaddr: 3.0.2 dst_nodeaddr: 3.0.0)



session_id=0 session_size=2
At 31.146925 HandoverMihoAP is forwarding MIH_Handover_initiate.request to PoS
```

Figure 39. Code Scenario IEEE 802.21 Signalling

6. Conclusions

Using UDLR mechanism that allows to create virtual bi-directional broadcast channels for the integration of wireless systems into heterogeneous infrastructure, has caused to eliminate some restrictions of communications, like freedom of movement device.

In addition, MIHF implementation on the IEEE 802.21 standard permits the handovers between heterogeneous networks due to communication systems unification in varying transmission characteristics. Hence, the mobility is not a problem for the reason that is possible to execute handover in heterogeneous networks, as bidirectional and unidirectional, only if there is implemented UDLR.

The execution handover time is increased using UDLR so could be a problem in communication. It uses complicated routing mechanisms that introduce delay when a tunnel is created or modified and also when there are packets forwarded.

As a future work, the tunnel implantation should be adjusted in order to create an efficient communication. Instead of use UDLR, it is important to use other solutions to value and compare the results.

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