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Relay Technologies in IEEE 802.16j Mobile Multi-hop Relay (MMR) Networks

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Abstract

IEEE 802.16 standard is created to compete with cable access networks. In the beginning end users are immobile and have a line of sight with base station, now it moved to mobile non line of sight (NLOS) with the new standard IEEE 802.16e and IEEE 802.16j. The new IEEE 802.16j standard which is an amendment to IEEE 802.16e is mobile multi hop relay (MMR) specification for wireless networks.

This paper discusses relay modes, relay transmission schemes and relay pairing schemes of IEEE 802.16j. Relay technologies such as transparent relay modes, non transparent relay mode, relay pairing schemes such as centralized relay pairing schemes, distributed relay pairing scheme, characterises of relay based networks such as throughput enhancement, capacity increase, cost reduction , relay techniques such as time domain frequency domain relay techniques and relay placement are also discussed in this paper. The paper also discusses about integration of IEEE 802.16j with IEEE 802.11.

Keywords: IEEE 802.16j, Relay pairing schemes, relay techniques, Relay modes, WIMAX, NCTUns, etc

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1. Introduction-Wireless Groups

Wireless systems for achieving high speed mobile wireless access services can be divided into two groups. The first group is International Mobile telecommunications-2000 [IMT-2000] which include wideband code division multiple access(W-CDMA), high speed downlink packet access (HSDPA), high speed uplink packet access (HSUPA), High speed packet access plus (HSUPA+), LTE/LTE-Advanced specified by 3GPP (3^{rd} generation Partnership project) , CDMA2000 1x and Ultra Mobile Broadband (UMB) specified by 3GPP2. The second group consists of IEEE 802.16e, IEEE 802.16j [1], and IEEE 802.16m [1] standard specified by IEEE 802.16 committee.

The second group is also called as Worldwide interoperability for Microwave access (WiMAX) standard is one of the 4G (4^{th} generation) telecommunication technologies that supplies wireless communication of data through different transmission links like point to multi point. Two groups which play role in the development of IEEE 802.16j standard is, IEEE 802.16 working group on Broadband wireless Access standard which develop standards and recommended practices to support the development of broadband Wireless metropolitan area networks and WiMAX forum which certify and promotes broadband wireless product based on IEEE 802.16 standard.

2. IEEE 802.16J Standard

The new task group IEEE 802.16j-2009 standard [1][2] of IEEE 802.16 Air interface for Broadband Wireless Access was officially established in March 2006, in order to support mobile multi-hop relay (MMR) specification, mesh mode is removed in the IEEE 802.16 -2009 standard.. The specification is shown in table 2, it is an amendment of IEEE 802.16e [3][4][5][6] standard for enhancing coverage throughput as shown in fig 1 and system capacity. It provides multi hop wireless connectivity where traffic between a base station (BS) and a subscriber station (SS) can be relayed through a relay station. This system enables mobile stations to communicate with a base station through intermediate relay station. Multihop relay station (M-RS) is an optional deployment that may be used to provide additional coverage or performance advantage in an access network. The RS may be fixed in location or, in the case of an access RS, it may be mobile access RS. Most of the time the RS will act as a BS and should have its own physical cell identifier, and also it should be able to transmit its own synchronization channels and control information. There should be no difference between cell control in RS and BS.

The radio link originating or terminating at an MS is named as the access link, but the link between BS and RS or between pair of RSs is called relay link. Theses access link and relay link can be used for uplink and downlink data transmission. This standard [7][8][9]defines the physical and the MAC layer specifications for MMR networks. The MAC layer supports functions such as network entry, bandwidth request, forwarding of PDUs, connection management and Hand over. The PHY layer adopts orthogonal frequency division multiple access (OFDMA) [1][2][3] as the primary channel access mechanism for non-line of sight (NLOS) communications in the frequency band below 11 GHz. Where multiple users are allocated separate set of slots, so that they can communicate in parallel. It supports point to multipoint (PMP) network topology where resource allocation is performed by BS on a per connection basis and the SSs are treated equally. MIMO [2] techniques have ability to exploit NLOS channels and increase spectral efficiency compared to single input single output (SISO) systems. It is able to provide high capacity and data rate without increasing bandwidth. The gain of MIMO is multiplexing gains, diversity gains and array gains.

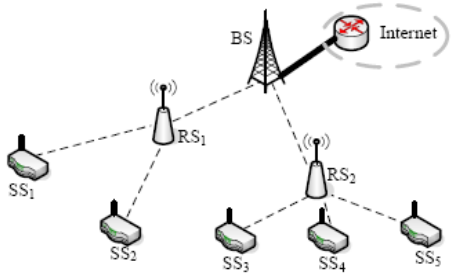

Fig 1: IEEE 802.16j Mobile multi hop relay (MMR) network.

The aim of this paper, to the best of our knowledge the first of its kind, is to give an overview of the relay technologies in IEEE 802.16j along with the different proposed and probable research solutions, starting right from the advent of IEEE

802.16e technology until today, thus identifying the research directions related to the existing and future technologies of WiMAX.. In this article, we focus on the mobile WiMAX , IEEE 802.16j mobile multi hop relay (MMR) technology and will use the acronym ' "IEEE 802.16j' instead of Mobile WiMAX IEEE 802.16j mobile multi hop relay (MMR) in the rest of the paper. The rest of the article is organized as follows. In section I, we briefly recapitulate the different relay modes, relay transmission schemes, and relay pairing schemes, techniques in IEEE 802.16j' . In section II we brief discussed about the different technical issues in Physical layer of IEEE 802.16j' and present a comparative study of the advantages of the different Physical layer technical issues. This is followed in section III by a brief discussion about the different technical issues in MAC-CPS layer of the IEEE 802.16j technology and their relevancy. This is followed in section IV by a brief discussion about the different technical issues in MAC-Security layer of the IEEE 802.16j technology. Section IV presents a brief comparative study between IEEE 802.16j and LTE technologies. Conclusions are drawn in Section V.

3. WiMAX Forum

The WiMAX forum [3] was established in 2003 to promote deployment of WiMAX as a broadband wireless access technology. It initiated several technical specifications and allows certification of WiMAX products. The network specification involve interaction with other standard organization include IETF, 3GPP, 3GPP2, DSL forum, and OMA.

4. RELAY MODES

Two different relay modes [1] are defined in this standard, transparent mode and Non- transparent mode.

a. Transparent Mode

The transparent relay mode [1] increases the throughput which facilities capacity increases within the Bs coverage area. It has no support to coverage extension because it does not forward framing information to BS. It is operated in two hop network topology and supports centralized scheduling only as scheduling is done only in BS. It uses CID based forwarding scheme and supports embedded and explicit mode of path management.

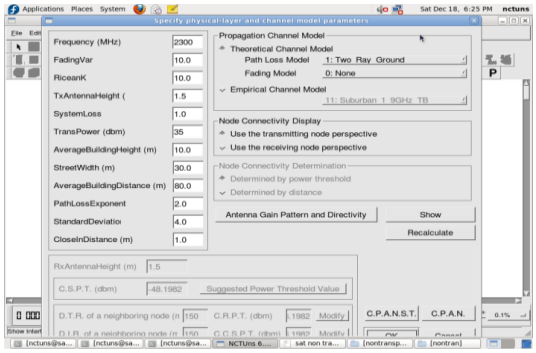

Fig 2: Non-tranparent mode channel parameters

b. Non transparent relay mode

The Non transparent relay mode [1] as in fig 3 is to increase the coverage extension of BS, here RS generate its own framing information and forward it to SSs. It operates is 2 or more hops and uses centralized or distributed scheduling mode, as scheduling is done in BS and RSs. It used CID and Tunnel based forwarding scheme and supports embedded and explicit mode of path management. The channel parameters are shown in fig 2

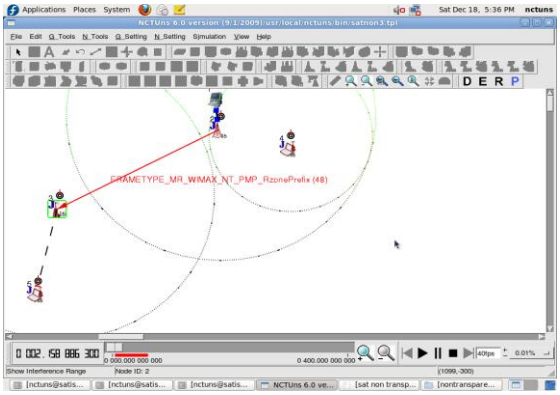

Fig 3: Non-tranparent mode of operation.

The transparent relay station does not transmit control message, permeable, FCH (frame control header, and DL/UL-MAP, as it only increases system throughput. The non transparent relay station transmit control message, permeable, FCH (frame

control header, and DL/UL-MAP, as it increases system throughput and increases cell coverage. Table 1 shows the difference between transparent and non transparent mode of operation.

5. Relay Transmission Schemes

There are many relay transmission schemes [24[26] proposed, they are Amplify and forward, selective Decode and forward, Demodulation and forward.

a. Amplify And Forward

Here the relay receives signal from the BS or SSs in the first phase it amplify this signal and forwards it to the SSs or BS in second phase. This is very simple and short delay relay transmission scheme.

b. *Selective Decode and Forward.*

Here also the relay receives signal from the BS or SSs in the first phase it decodes the signal and the decoded data is checked for cyclic redundancy check (CRC) then the decoded data is coded and forwards it to the SSs or BS in second phase. This scheme avoids error propagation through the channel.

c. Demodulation and Forward.

Here also the relay receives signal from the BS or SSs in the first phase it demodulate the signal without decoding and then it modulates and forwards it to the SSs or BS in second phase.

TABLE-1

S.No	Transparent Mode	Non Transparent Mode
1.	Supports Centralized scheduling - as scheduling done only in base station	Supports Centralized or Distributed scheduling- as scheduling done in base and relay station
2.	Use CID based forwarding scheme	Use Tunnel based or CID based forwarding scheme
3.	Use only 2 hops	Use 2 or more Hops
4.	Does not provide coverage extension	Provides BS coverage extension.
5.	Low Relay station cost.	High Relay station cost.

***6.* Relay Pairing Schemes**

Pairing scheme [24] is developed for having collaboration between RSs and BS in data transmission. This will improve the coverage and throughput of the mobile multi hop relay (MMR) networks. There are two pairing schemes proposed, Centralized pairing scheme and distributed pairing scheme. The other Relay pairing schemes are Random Relay Pairing Schemes and Opportunistic Relay Pairing Schemes

a. *Centralized Relay Pairing Schemes*

In this scheme the BS will act as a control node and collects the channel and location information from all the RSs and SSs and then make the pairing decision. This information must be formed as a service set and periodically updated in the local BS to capture dynamic changes of SSs This scheme requires more signaling over head, and can achieve better performance gains.

b. Distributed Relay Pairing Schemes

In this scheme, RS collects the channel and location information from all the nearby SSs and then makes the pairing decision. First each RS identify its service set of neighborhood SSs and also the channel conditions between its BS as well as its SS, those RS with single service set each randomly selects a time slot from the N- slots in the pairing scheme. If multiple RS choose the same time slot then collusion occurs and those RS will be trying again in the next pairing scheme.

7. Relay Placement

By deploying relay stations [26] in lower SINR cell boundary area the system capacity, throughput per user, and the system reliability can be enhanced. The Relay placement is formulated as an optimization problem and solved by and iterative algorithm, under the assumption that MS distribution is uniform. In some cases large geographic area under non

uniformly distributed traffic demand is considered. The locations of BS are determined in the first stage network deployment. An RS location algorithm is designed to locate RSs.

8. Characteristics of Relay Based Networks.

Relay based networks[15][16][17][18] has small form factor, low cost relays associated with Base stations. Three main benefits provided from relay based architecture over single {hop architecture are throughput enhancement, coverage increase and deployment cost.

a. Throughput Enhancement:

It is expected to increase system capacity by deploying RSs in a manner that enables more aggressive spatial reuse.

b. *Coverage Enhancement/Extension*:

The relay technology is expected to improve the coverage reliability in geographic areas that are severely shadowed from the BS and/or to extend the range of a BS.

c. *Cost Reduction:*

Relay based systems have the potential to deliver cost gains over traditional single {hop wireless access systems. Using RSs, an operator could deploy a network with wide coverage at a lower cost than using only (more) expensive BSs to provide good coverage and system capacity.

9. Relaying Techniques:

The Relaying techniques[15][16][17][18] [26] include the conventional techniques (i) time domain relaying, (ii) frequency domain relaying and (iii) hybrid time/frequency domain relaying and the current technique that is interest among the research community is (iv) co-operative technique.

a. Time Domain Relaying:

In this scheme relays access the Medium in time multiplex. The resources are further divided in time in either the DL or UL to allow the relay station to receive and transmit data.

b. Frequency Domain Relaying:

Relays are operating on different frequency channels. The main advantage of this scheme is that relays can transmit

and receive data simultaneously.

c. Hybrid Time/Frequency Domain Relaying:

Relays are operating periodically on different frequency channels to forward data. The idea here is to switch between two frequencies in order to allow the BS to transmit to its client while the relay is forwarding data on another frequency.

d. Cooperative Relaying Techniques:

Such techniques can significantly enhance the performance of relay based systems by multiple RSs cooperatively transmitting the same data to a SS or the BS, i.e. in the DL or UL. This leads to similar benefits than in MIMO systems with transmit/receive diversity and spatial multiplexing.

10. Multiple-Input Multiple-Output (MIMO) Communication for IEEE 802.16j.

MIMO- Multiple-Input Multiple-Output techniques have been used in IEEE 802.16d/e/j to improve cell coverage and increase average user with in the cell. MIMO transmission [26][11[12] is used to increase the data rate of the communication between a given transmitter-receiver pair and/or improve the reliability of the link. Use of multiple antennas can improve the achievable rates of users in the network with given frequency. As MIMO technology matures it is expected that MIMO will be widely used for wireless communication. For Next Generation WiMAX a system is to support at least up to 8 transmit antennas at the base station, 4 streams and Space-Time Coding. MIMO futures such as closed-loop MIMO will be included in future WiMAX More specifically, it has been already decided to support closed-loop MIMO using Channel Quality Information, Precoding Matrix Index and rank feedback in future systems.

The MIMO techniques [32][33] are Single User MIMO (SU-MOMO) , Multi User MIMO (MU-MIMO) and cooperative MIMO. The adoption of MIMO techniques often requires a tight design integration of PHY, medium access control (MAC), and higher layers of IEEE 802.16j. The key MIMO techniques are ; Open-loop transmit diversity in DL, Open-loop spatial multiplexing in DL, Open-loop transmit diversity in UL, Open-loop spatial multiplexing in UL, Collaborative spatial multiplexing in UL (UL MU-MIMO), Adaptive beam forming including DL SDMA (DL MU-MIMO), Closed-loop antenna grouping/selection, Closed-loop codebook-based pre-coding. These above features are included in Release 1.0 and 1.5 of WiMAX forum.

a. Single User MIMO (SU-MOMO)

In SU-MOMO [32] the transmitter and receiver are equipped with M and N antennas. The channel is Rayleigh or Rician fading channel. Based on the full or partial availability of Channel State Information (CSI) to receiver and transmitter SU-MOMO is classified in to open loop SU-MOMO and closed loop MIMO.

b. Open loop SU-MOMO

Open-loop MIMO systems[32] are more desirable in mobility applications because they do not require CSI as 802.16e support mobility of up to 120 km/h. 802.16e adopts space-time coding (STC) as the main open-loop MIMO scheme. STC is supported for both the uplink and downlink, for up to four transmit antennas, and for a multiplexing rate up to 4. STC option allows low complexity decoding, while others are optimized for high complexity decoding. Cyclic delay diversity (CDD) is another open-loop scheme. Too much CDD delay may reduce the receiver's channel estimation accuracy due to the augmented frequency fluctuation.

c. Closed- loop SU-MOMO

Closed-loop systems[33] can achieve better performance than open-loop systems by exploiting CSIT.

d. Multi User MIMO (MU-MIMO)

MU-MIMO [32] allows multiple SSs to spatially share the same time-frequency resource for the improvement of both the cell spectral efficiency and average user experience.

e. Distributed MIMO and Relay in IEEE 802.16j.

Among BS, RS(s), and SS, a distributed MIMO system is formed with all the transmit antennas of BS and RS on one side and the receive antennas of the destination SS on the other side.

New MOMO techniques [33] are open-loop multiuser MIMO, and collaborative multicell MIMO. In the multicell MIMO multiple BSs collaborate to serve multiple SSs in the edge region of the BSs' cell. A precoding entity in the network backhaul will decide the precoding vectors used for all SSs in all the BSs. The multicell MIMO system has the potential to eliminate dominant intercell interferences, while offering multiplexing rate and diversity gain.

11. IEEE 802.16j Protocol Layering

IEEE 802.16j protocol layering[13][14][15][26] consists of Data/Control Plane and Management plane. The Data/Control Plane defines PHY and MAC layers. The Management plane defines respective management entity of PHY and MAC layers.

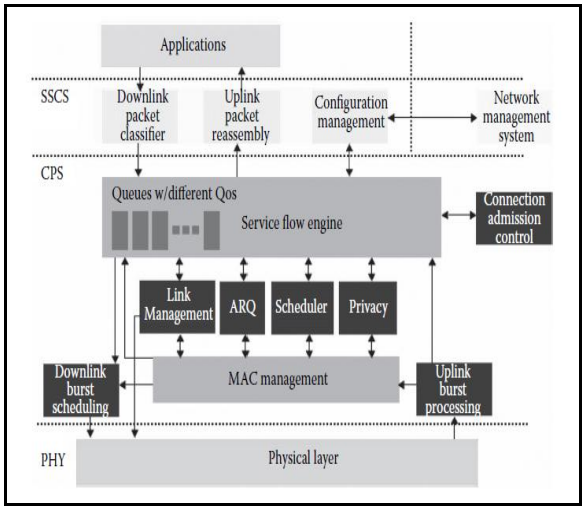

Fig 4: IEEE 802.16j MAC –CPS and SSCS sublayers

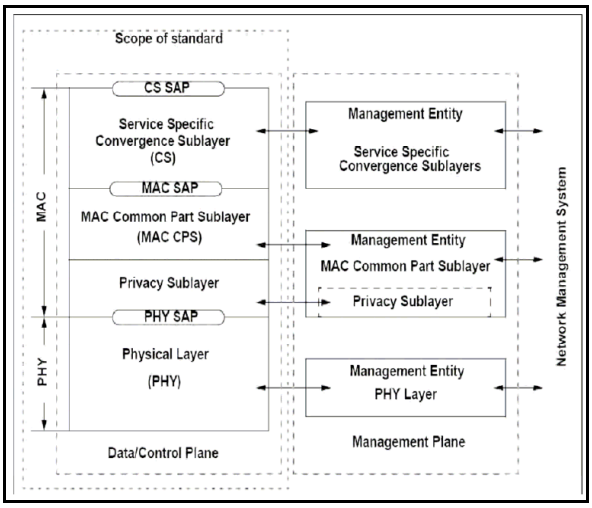

Fig 5: IEEE 802.16j protocol layering.

a. Data /Control Plane

The IEEE 802.16j data /control plane as in fig 5 includes the Physical layer (PHY), MAC common part sub layer (MAC-CPS) and MAC convergence sub layer (MAC-CS). The MAC common part sub layer as in fig 4 includes connection admission control, Link management, ARQ, scheduler Downlink/uplink burst processing. The MAC convergence sub layer Network management, configuration management, uplink packet reassembly and downlink packet classifier.

b. Management Plane:

The management plane as in fig 5 includes the corresponding Management entity of Physical layer (PHY), MAC common part sub layer (MAC-CPS) and MAC convergence sub layer (MAC-CS).

12. IEEE 802.16j [WIMAX] Integration with IEEE 802.11n [Wi-Fi]

WiFi also called as WLAN or IEEE 802.11 provide wireless connectivity to local networks in unlicensed frequency band and offers low or free of cost internet connectivity, but WiMAX designed for point to multi point (PMP) operates in licensed and unlicensed band provides broad band internet connectivity to last mile access. In WiFI subscriber stations are connected through access points (AP), but WiMAX subscriber stations are connected to base station (BS). The IEEE 802.16j standard provides PMP mode for SS outside the BS coverage area and use dedicated relay stations (RS) to support mobile nodes.

For integration of Wi-Fi with WiMAX different scenarios are considered such as single mode client scenario, Dual mode client scenario, Backhaul scenario, multi hop heterogeneous scenario, Dual gate way single mode client scenario, Dual gate way Dual mode client scenario, Mobile / moving Networks scenario.

In single mode client scenario SSs are connected to either BS1 or AP1 that is SS1 to BS1 if it is within the coverage area of BS1 and SS2 to AP1 if it is within the coverage area of AP1.

In backhaul Scenario the SS1 are connected to internet through point to point backhaul connection (BSi-BSj). In dual mode SS1 is connected to both WiMAX BS and Wi-Fi AP. In dual gate way mode, a dual gateway will connect to SS and BS, that is provides coverage area of BS. In multi hop mode an RS can provide coverage extension to SS for both BS and also AP. In mobile network scenario a mobile gateway can be used by external clients outside the coverage area of Wi-Fi / WiMAX.

13. Conclusion and Future Works

The new IEEE 802.16j standard which is an amendment to IEEE 802.16e is multi hop relay specification for wireless networks. Relay technologies such as transparent relay modes, non transparent relay mode, relay pairing schemes such as centralized relay pairing schemes, distributed relay pairing scheme, characterises of relay based networks such as throughput enhancement,capacity increase, cost reduction , relay techniques such as time domain frequency domain relay techniques and relay placement are also discussed in this paper. In future we are planning to solve some of the technical issues such as Network planning, Relay placement, scheduling services, bandwidth allocation etc.

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