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Methods to make Multi-Hop Relay Networks More Reliable

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Abstract

The study of broadband internet connection through end-user devices is currently trending. The high performance of 4G cells is hampered by shadowing and multipath problems. Network coverage and throughput may be enhanced with the use of Relay Stations (RS) in Multi hop Relay (MHR) networks. Path selection and RSs deployment are two problems that may have a major impact on impacts the system's QoS (Quality of Service). Path selection using a Load Aware Routing Metric (LARM) and RS deployment using a simple Burst Profile (BP) are explored in this study as ways to improve the MHR networks' quality of service. Downlink (DL), Backhaul Performance (BP), Link Efficiency (LE), and Worldwide Interoperability for Microwave Access (Wi-MAX) are some examples of keywords.

Introduction:

excellent data rate with excellent quality of service1 is a requirement of current Broadband Wireless Access (BWA) technologies. Cheaper alternatives to DSL internet include Wi-MAX and Long Term Evolution-Advanced (LTE-A). The 3GPP LTE-A and IEEE 802.16j working groups have collaborated to boost network speed and coverage .have made progress with MHR design. The hope is that the Base Station (BS) deployment and maintenance costs will go down with this design. Orthogonal Frequency Division Multiple Access (OFDMA) is used in the DL3 by Wi-MAX and LTE networks. The BS allocates its radio bandwidth to the MSs and RSs that have requested it. There are two types of connections in this design: radio and access. Access connections are those that begin or end with MS.

Radio connections connecting RSs to one another or a BS to a RS. It's possible that each MS in a given MHR cell takes a slightly different DL route. At some point, the MS will be limited to a single service route. If a bad route is chosen, throughput will be reduced. In the literature, several path selection algorithms ignore the connection between possible routes. problem with overloading4-8. Taking into account the link overloading problem, the LARM algorithm is shown to perform better than other, more standard methods in9. The LARM method's performance is used as a reference point in this work, and potential enhancements to the current approach are also discussed. This research also highlights an effective BP-based RS deployment technique to significantly enhance network throughput. Following this structure is the remainder of the paper. Section 2 provides an introduction to IEEE 802.16j BP. Path selection based on a network model and LARM are explored in detail in sections 3 and 4, respectively.In Section 5, we'll talk about the RS identifying technique that uses a BP-based number. The simulation findings are discussed in Section 6, and the study is wrapped up in Section 7.

Nomenclature	
r	coding rate
R_p	repetition rate
M_{MS}	number of MSs in the cell
M_P	number of DL paths
T	Traffic
c	Link cost
C	Path cost

Overview of IEEE 802.16j Burst Profiles

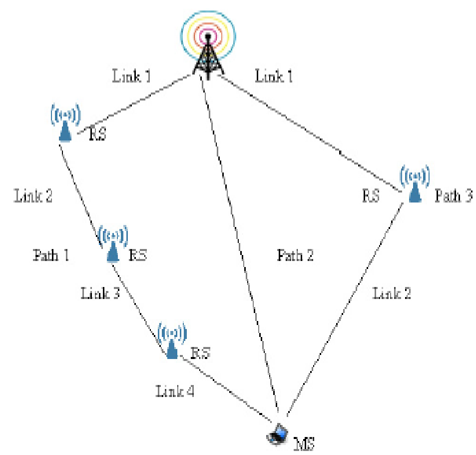
Table 1. BPs supported in IEEE 802.16j

BP ID	Modulation (m)	Coding scheme	Code Rate(r)	Repetition rate (R_p)	LE
1	QPSK(2)	CC/CTC	1/2	6	1/6
2	QPSK(2)	CC/CTC	1/2	4	1/4
3	QPSK(2)	CC/CTC	1/2	2	1/2
4	QPSK(2)	CC/CTC	1/2	1	1
5	QPSK(2)	CC/CTC	3/4	1	3/2
6	16-QAM(4)	CC/CTC	1/2	1	2
7	16-QAM(4)	CC/CTC	3/4	1	3
8	64-QAM(6)	CC/CTC	1/2	1	3
9	64-QAM(6)	CC/CTC	2/3	1	4
10	64-QAM(6)	CC/CTC	3/4	1	9/2
11	64-QAM(6)	CTC	5/6	1	5

During the phase of resource allocation, MHR-BS is in charge of providing RS and MS with the appropriate BPs. Table 1 displays the BPs that work with the IEEE 802.16j standard. Convolutional Codes (CC) and Convolutional Turbo Codes (CTC) are two types of Error Correction codes used extensively in this standard. It quadrature phase shift keying (QPSK) and quadrature amplitude modulation (QAM) with modulation sizes of M=16 and 649, respectively. Table 1 shows that the LE is lowest for the lowest BPs and highest for the highest BPs. The MSs and RSs with the worst signal quality will be assigned lower BPs, while the ones with the best signal quality will be assigned higher BPs10. When RSs were first introduced in The MHR network shortens the gap between bases and boosts throughput generally. Table 1 does not reflect the fact that BP is distributed in accordance with the received SNR. In addition to distance and time, hop count is a common route selection criterion in the literature5. In certain cases, the algorithms propose going with a route with the fewest possible stops. However, decreasing the BP use of the system is the minimal hop count, which leads to greater distances between stations. The result is slower data transfer across the network. The authors of9 recommend LE as the best statistic to use when deciding which routes to take.

Network Model:

Typical nodes in an MHR network are shown in Fig. 1 (a). Figure 1(a) shows that there are three potential outcomes for MS. The MHR-BS to MS route is the direct route, whereas routes 1 and 3 are indirect routes. Multiple connections may be part of each possible indirect route. Path 1 has four connections, whereas Path 3 has just two.



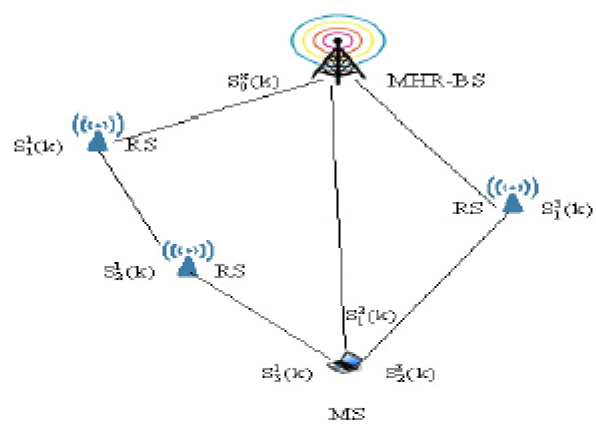


Fig. 1 (a). MHR Networks Fig. 1 (b). Each path indicated by the stations

We define the following variables to explain the proposed LARM path selection algorithm. M_{MS} is the number o MSs in the cell. MS(k) represents k^{th} MS in the cell, where k=1,2… M_{MS}. M_p is the number of DL paths. $P^l(k)$ is the l^{th} path from MHR-BS to k^{th} MS, where l=1,2… M_p. $N^l(k)$ is the length of l^{th} path. $P^l(k)$ can be represente as the sequence of stations[9].

$$P^l(k) = \{S_0^l(k), S_1^l(k) \ldots S_{N^l(k)}^l(k)\} \quad (1$$

where $S_0^l(k)$ is the MHR-BS, $S_{N^l(k)}^l(k)$ is the required k^{th} MS and the others are intermediate RSs. $L_{i,i+1}^l(k$ represents the link between the stations $S_i^l(k)$ and $S_{i+1}^l(k)$ of l^{th} path. The superscript indicates path index and th subscript indicates station index. Fig. 1 (b) explains how paths can be represented by the sequence of stations.

LE for a particular BP can be calculated as[9],

$$LE_{i,i+1}(k) = \frac{mr}{R_p} \quad (2$$

where $m = \log_2 M$. The LE calculated in (2) is for one subcarrier. As per IEEE 802.16j standard there exist 4 data subcarrier in a time slot[11]. The total amount of traffic (in bytes) an OFDMA slot can transmit in a link is give as,

$$T_{i,i+1}(k) = \frac{48.LE_{i,i+1}(k)}{8}$$

$$T_{i,i+1}(k) = 6.LE_{i,i+1}(k)$$

Link cost is the ratio between link load and LE. The co for k^{th} MS is given as[9],

$$c_{i,i+1}^l(k) = \frac{D_{i,i+1}^l(k)}{6.LE_{i,i+1}^l(k)}$$

where $D_{i,i+1}^l(k)$ is the traffic load (in bytes) of the link l^{th} path is given as,

$$C^l(k) = \sum_{i=0}^{N^l(k)} c_{i,i+1}^l(k)$$

LARM Path Selection Algorithm

The following steps are executed in sequence to find the optimal path.

Step 1: If $\{\text{DL Traffic of MS(k)}\} < \{\text{available resources of MHR} - \text{BS}\}$

Then do

for $l=1, 2 \ldots M_p$

for $i=0,1,\ldots N^l(k)$

Compute $C_{i,i+1}^l(k)$ using equation (5)

Compute $C^l(k)$ using equation (6)

Step 2: Select path $P^l(k)$ with minimum $C^l(k)$.

The RRUI algorithm was first proposed in the year 4. In Fig. 2 we can see that MS (2) offers three DL options. Let's assume RS (1) already provides backing for MS (1). There is one direct route from MHR to BS to RS to MS(2), and two indirect routes from MHR to BS to RS to MS(2). Assume further that MS (2) can go to RS (1) in the cheapest possible way. Since The connection between MHR-BS and RS (1) is overloaded due to the fact that RS (1) already supports MS (1). The efficiency of MS (1) and MS (2) is diminished as a result. When there is a lot of traffic, the link overloading problem becomes worse. Reducing the data rate also causes transmission delays that aren't essential. The quality of service of time-sensitive programs is impacted. The LARM method adjusts the RRUI algorithm such that the MHR-BS always takes the route with the lowest possible cost to serve the MS (2). If the connection overloading problem persists, BS will switch to the next cheapest available alternative. In this scenario, MS (2) must use RS (2) rather than RS (1) for service. It is also important to highlight that RS (2) shouldn't have any connection overloading issues. The RRUI algorithm is modified as described below to produce the LARM algorithm.

Step 1: Use RRUI Algorithm and calculate cost of each DL pa

Step 2: Verify all the links in the minimum cost path satisfies t

If $\{\text{Total traffic through the link } L_{i,i+1}^l(k)\} < \{\text{Ca}$

Then

Use minimum cost path as optimum path.

else

Repeat step 2 for the next minimum cost path.

Step 3: Repeat step 2 until the identification of optimum path.

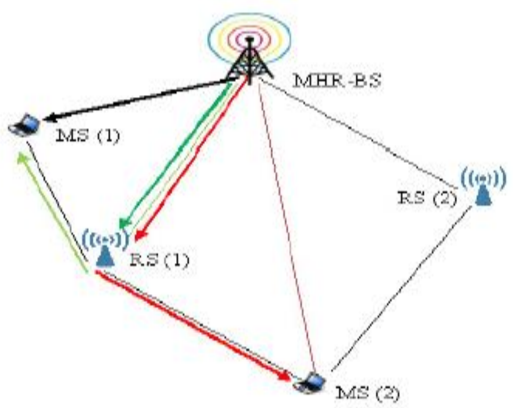


Fig. 2. Link overloading problem

BP Based Optimum RSs Identification Scheme:

Increasing the number of RSs may boost coverage and capacity, but it can also cause issues with radio resource management.12. Increasing the total number of RSs in a cell increases the total number of DL pathways available to each MS. Increasing the number of possible DL pathways increases the likelihood of path selection issues, such as undue latency. The holdup

is the unintended consequence of time-limited software. The optimal choice of RSs for a given cell was not addressed in the original LARM design. Many scientists are still investigating this question. The BS must employ larger BPs, which will increase the number of RSs, to provide better service even for cell edge customers. The current suggested strategy balances the need for RSs at the cell edge with the overall network throughput. In Section 6, we see an example of how this method works in practice.

Simulation Results and Discussion:

To evaluate the efficacy of the suggested methods, we use the Matlab program. The LARM route selection system is the primary focus of the first half of this section. We model the system using center-excited MHR-BS, which is anticipated to provide 17 Km of coverage in practice. We employ six Fixed Relay Stations (FRS) to increase coverage and capacity inside the cell. It FRS are also expected to be stationed at the cell's edges. We have not made any efforts to ensure that our BS and RS placements are ideal in this work. All BPs numbered 5, 4, 6, 7, 4, and 6 are presumed to be in use by the RSs numbered 1 through 6. Two cases, one with link overloading and one without, are presented as examples in this work. We've considered three different variations for each situation, including no RS, RRUI route selection, and LARM path selection. The assumption of MS homogeneity across the cell

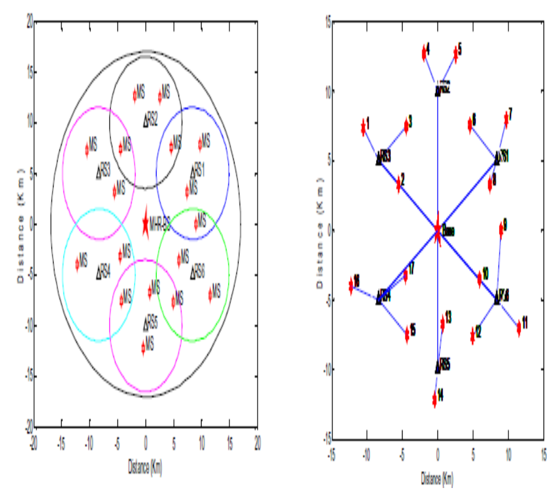


Fig. 3 (a). Scenario 1: No link overloadi Fig. 3 (b). Different MSs getting service from different FRS inscenario 1

There is no link overloading problem in the case shown in Fig. 3 (a). In Fig. 3 (b), we can see how the RRUI and LARM allocation algorithms determine the route taken by each MS. When each RS is responsible for a significant number of MSs, the effectiveness of RRUI and LARM are equivalent. Multiple MSs play out this same scene. in unexpected parts of the cell. When no link overloading is a concern, simulation studies show that RRUI and LARM function similarly. Comparing the RRUI and LARM scheme to a system with no relay, the latter gives an average net throughput of 9.5 Mbps for 100 runs. Figure 4(a) depicts this finding. Scenario 2 introduces a connection overloading problem by placing many MSs in close proximity to the same RS. Fig. 5 (a) depicts one such example from the testing phase. Link overloading occurs from RS3 to MS6 and MS7, as seen in Fig. 5 (b). The service for these MSs, from RS3 to RS, is scheduled by BS using the LARM system. The simulations are run 100 times to account for the link overloading problem, and the average network throughput is shown in Fig. 4 (b). It is obvious from the data that the LARM system provides a net throughput of 10.6 Mbps, whereas the RRUI strategy provides only 9.5 Mbps.

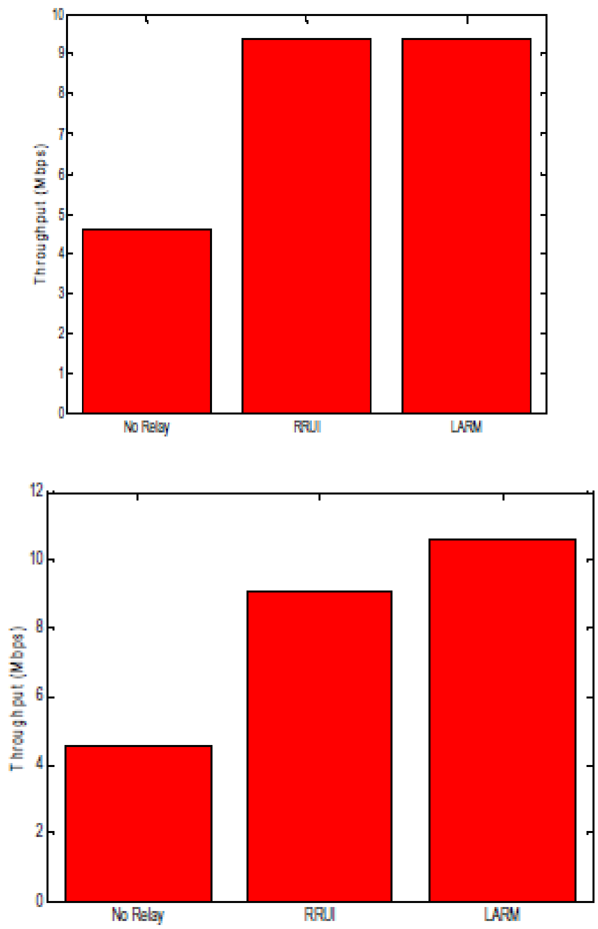


Fig. 4 (a). Throughput comparison between LARM, RRUI and Fig. 4 (b). Throughput comparison between LARM, RRUI and No

No relay cases for scenario 1 with no link overloading relay cases for scenario 2 with link overloading issue

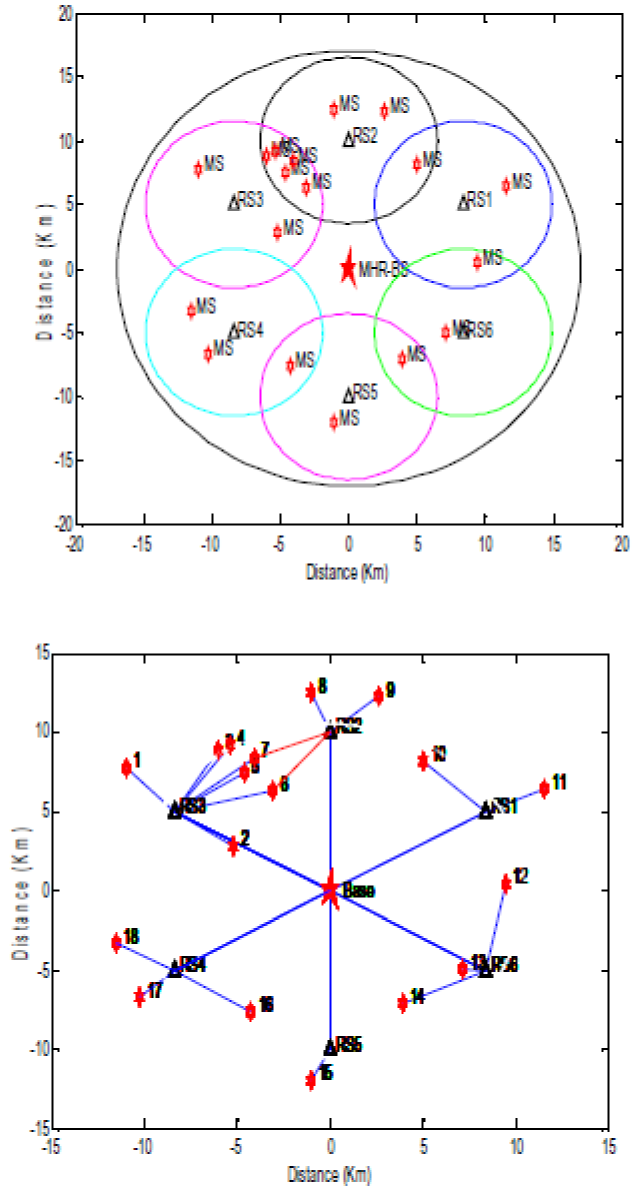


Fig. 5 (a). Scenario 2: More MSs are located in RS3 than other RSs Fig. 5 (b). Service of few MSs are transferred from RS3 to RS2 based on LARM

We have utilized the IEEE 802.16 macro cell suburban route loss model13 to simulate the suggested method for determining the optimal number of RSs. The model relies mostly on a hilly landscape with a medium-to-high tree cover.

Heavy scattering means significant route loss. As a result, even a short distance from the MHR-BS will have a significant loss of route. The formula for the path loss is:

$$PL_{802.16}(d)[dB] = PL_{free}(d_0) + 10\eta \log_{10}\frac{d}{d_0} + k_f +$$

where d_0 is reference distance, $PL_{free}(d_0)$ is the free s
between the communication stations, k_f is the correlatio
receive antenna correlation coefficient and η is the constan

The standard distance of 100 meters is used in all simulations. It is expected that the antenna heights of the transmitter and receiver are 30 and 2 meters, respectively. The agreed-upon carrier frequency is 2 GHz. The simulation takes into account a tiny cell with a range of 450 meters. In this article, we compare three distinct scenarios. Example 1 and case 2 addresses BP 7 and BP 9, whereas case 3 addresses the suggested remedy. According to the IEEE 802.16j BP list, the minimum received SNR required for BP7 is 17.63 dB, while for BP9 it is 24.15 dB. In scenario 1, the signal-to-noise ratio (SNR) reaches roughly 17.63 dB at 200 meters. A RS is set up at 200m to improve coverage and capacity. Once again, at 320 meters, the received SNR hits 17.63 dB. So, a second RS is set up 320 meters from the base station. To go 450 meters with BP 7, you'll need two RSs. As a result, we see an improvement in overall network speed to 16 Mbps. In scenario 2, the SNR is received at 140, 230, 320, and 420 meters and reaches 24.15 dB. With BP 9, we need 4 RSs to cover the whole 450 meters. This raises the typical transfer rate to 26 Mbps. Unfortunately, additional RSs are required for this. The deployment and maintenance cost rises in tandem with the throughput as the number of RSs increases. To make up for the concession, a single RS, operating on BP 9, might be stationed at a distance of 140 meters. After that, BP 7 may be used to deploy two RSs at 270 and 380 meters.While only using 3RSs, this approach is closer to scenario (2) in that it can provide a net throughput of around 24 Mbps. Throughput figures for three distinct scenarios are shown in Fig. 6(a) and (b).

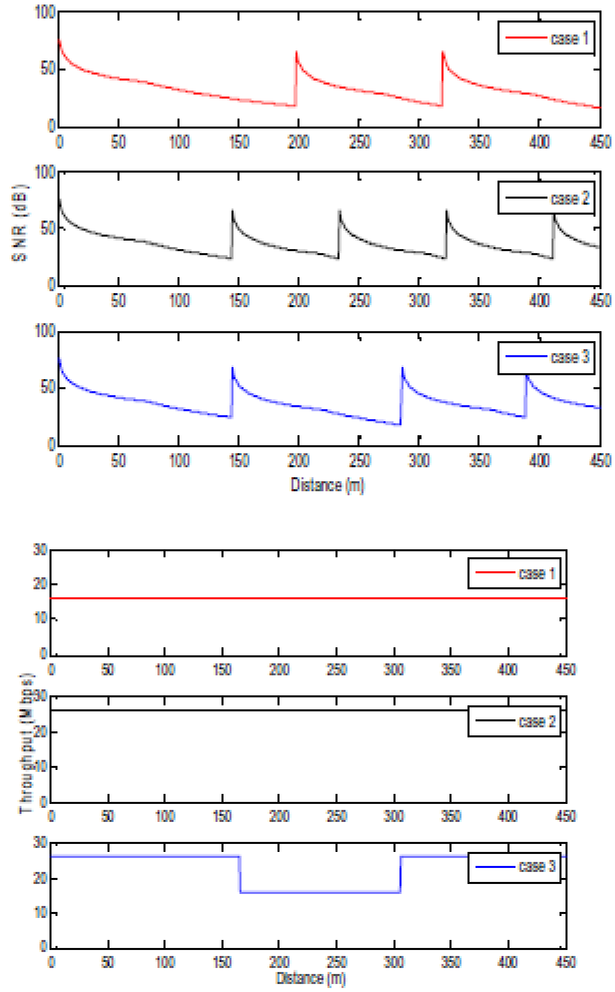


Fig. 6 (a). SNR (dB) vs. Distance (m) for three different cases Fig. 6 (b). Throughput (Mbps) vs. Distance (m) for three different cases

Conclusion:

This study discusses a low-complexity BP-based optimal number of RSs identification technique and a LARM-based route selection. The simulation findings show that compared to the RRUI system, LARM provides a 10.37% increase in average network throughput. Real-world limitations such as connection fault and channel info, For future efforts, feedback latency must be taken into account. It is also shown that the throughput may be maximized with a little increase in the number of RSs by using an identifying strategy based on BP. This method was designed specifically for MSs found in the cell's periphery. Each MS in the cell requires a unique adaptation.

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