ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2011. No. 6(112)
ELEKTRONIKA IR ELEKTROTECHNIKA

AUTOMATION, ROBOTICS
T 125
AUTOMATIZAVIMAS, ROBOTECHNIKA

Simulation of IEEE 802.16j Mobile WiMAX Relay Network to Determine the Most Efficient Zone to Deploy Relay Station

V. Bulbenkiene, V. Pareigis, A. Andziulis, M. Kurmis, S. Jakovlev
Department of Informatics Engineering, Klaipėda University,
Bijunu str. 17, LT-91225 Klaipėda, Lithuania, phone: +370 46 398986, e-mail: iik.jtf@ku.lt

crossref http://dx.doi.org/10.5755/j01.eee.112.6.451

Introduction

Wireless technologies usage is rapidly expanding and WiMAX (*Worldwide Interoperability for Microwave Access*) technology is more widely used. The new WiMAX standard first uses relay stations (RS) for better service quality. Published works analyses relay stations influence to the quality of service, as well as analyses relay stations resource distribution and management, creating network topology for better service quality [1-4]. However there are no specific studies done to determine most efficient zone to deploy RS.

To achieve this IEEE 802.16j simulation was made with NCTUns a network simulator and emulator that directly use's real-life TCP/IP protocol stack and applications to generate accurate simulation results. This papers goal is to determine which modulation zone is the most efficient for relay stations to be deployed to achieve maximal network throughput. This paper also analyzes the number of subscriber stations impact to the network throughput with slot load in one frame and optimal relay stations number connected to one base station to ensure the highest quality internet connection.

Simulation of IEEE 802.16j mobile WiMAX relay network

As the extension of the current standards (IEEE802.16d and IEEE802.16e), IEEE 802.16j aims at defining the multi-hop relay specification including the MAC and the physical (PHY) layers (Fig. 1) [4].

WiMAX uses adaptive modulation coding AMC, and the optimal modulation is automatically selected depending on the signal quality (Fig. 1). For example, if the relay station or subscriber station is far away from the nearest base station the connection is guaranteed to it, but with low-level modulation, that is the maximum speed is slowing down. It is investigated when signal is modulated with QPSK (*Quadrature Phase-Shift Keying*) and QAM (*Quadrature amplitude modulation*) modulation [5].

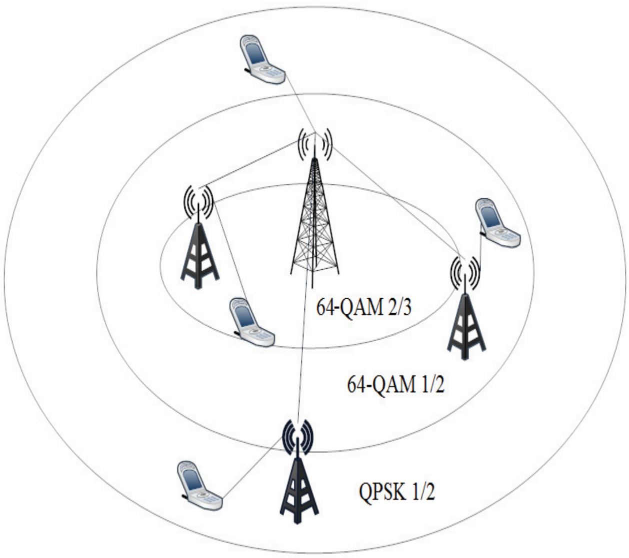

Fig. 1. The typical topology of relay network [4, 5]

According to the newest baseline document [4], two modes, non-transparent mode and transparent mode, are specified in table 1 to support those application scenarios.

Table 1. Transparent RS and Non Transparent RS [6]

	Transparent RS	**Non-Transparent RS**
Coverage extension	No	Yes
Number of hops	2	2 or more
Inter RS cell interference	None	High
Performance	In BS coverage: high; Outer BS: None	In BS coverage same as 802.16e; Outer BS coverage: Medium
RS Cost	Low	High
Scheduling	Centralized scheduling only	Centralized/ Distributed scheduling

IEEE 802.16j is a new standard and no such products are available yet in the market for researchers to evaluate its performances. NCTUns [6-8] is a powerful tool for simulations and emulations. It has two unique features. First, it uses the real-life TCP/IP (or UDP/IP) protocol stack in the Linux kernel to conduct simulations and emulations. Second, it can run up any real-life application programs on simulated nodes during simulation to generate realistic network traffic in simulations. These capabilities enable NCTUns to generate high-fidelity simulation results and evaluate the performances of real-life applications under various network conditions. It supports both the transparent mode and non-transparent mode defined in the IEEE 802.16j standard.

During simulation, channel model was developed. Simulation was made in non-transparent mode. Additional condition was made that the station isn't exposed to a signal fading and that there is no additional signal interferences in its route like tall buildings, forests and etc. Stations signal transmission power was set at 30 dBm. Data network for sending and receiving bandwidth has been allocated: 70% uplink and 30% downlink.

The second table shows the adjusted OFDMA (*Orthogonal Frequency-Division Multiple Access*) parameters (that we use in simulation) in NCTUns program. Corrections of these parameters were made that were in line with the European Union.

Table 2. The OFDMA parameter values used in the simulations

OFDMA parameters	Definition	Value
Frequency		3,5 GHz
Channel bandwidth		10 MHz
FFT size	128, 512, 1024, 2048	2048
Subcarrier		840
DL subcarrier allocations		30
UL subcarrier allocation		35
Sampling factor (n)	28/25, 8/7	28/25
Sampling frequency (Fs)		11.2 MHz
CP ratio	1/32,1/16,1/8, 1/4	1/8
CP time		11.425 us
Symbol time		102.825 us
Frame duration	2, 2.5, 4, 5, 8, 10, 12.5, 20	10 ms 20 ms
Physical slot		0.357143 us
TTG		90 PS
RTG		90PS

COST (*COperation européenne dans Le Domaine de la recherche Scientifique et Technique*) 231 HATA empirical channel model was used in this simulation. It contains corrections for urban, suburban and rural (flat) environments. COST 231 HATA is expected owing to the mobile scenario for which this model is most appropriate [9].

Third table shows corresponding modulation type with data rate transfer (Mbps) without relay stations when bandwidth is 10MHz.

Table 3. Modulation type with data rate (Mbps) [10]

Modulation	Data Rate (Mbps)
QPSK 1/2	4.043
QPSK 3/4	6.048
16QAM 1/2	8.064
16QAM 3/4	12.096
64QAM 2/3	16.128
64QAM 3/4	18.144

Results and discussions

Relay station was placed in QPSK ½, QPSK ¾ and 16QAM ½ zones in order to examine throughput increases during simulation. Information of throughput increase is shown in Fig. 2, Fig. 3 and Fig. 4, by changing relay stations place ant modulation type.

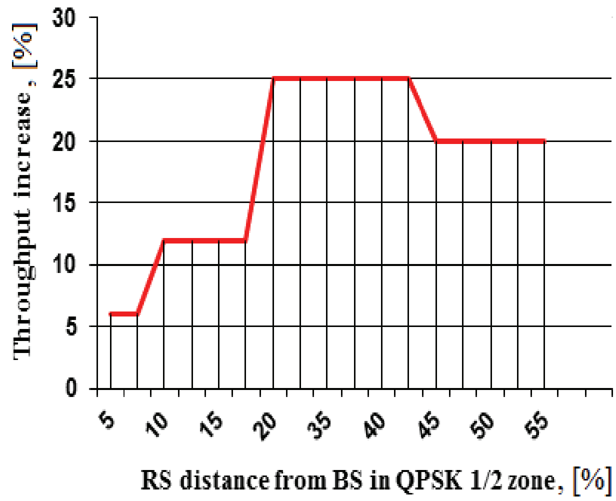

Fig. 2. Maximum network throughput increase in QPSK ½ zone

Changing relay stations place in QPSK ½ modulation zone throughput increase was 25% between base station and subscriber station (Fig. 2).

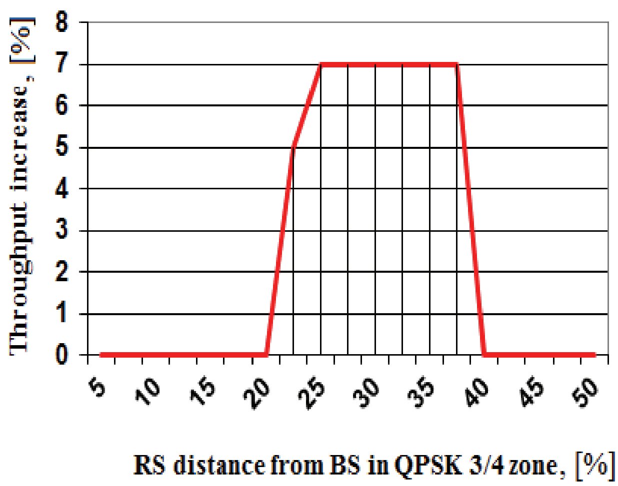

Fig. 3. Maximum network throughput increase in QPSK 3/4 zone

When relay station was operational in QPSK ¾ zone, by changing the position of relay station throughput increases up to 7.2% (Fig. 3).

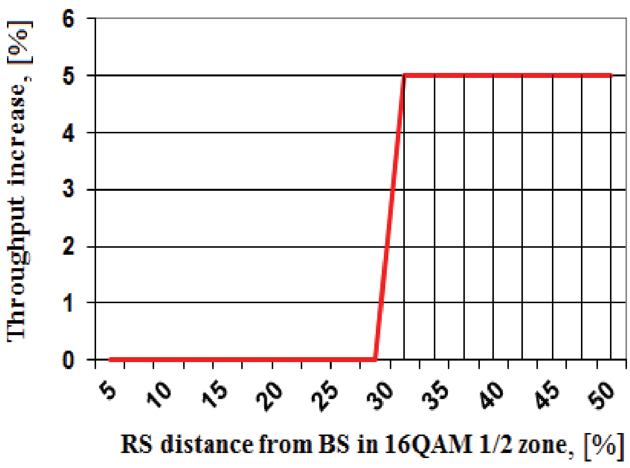

Fig. 4. Maximum network throughput increase in 16QAM ½ zone

When relay station is operational in 16QAM ½ zone, by changing the position of relay station data throughput increases up to 5% (Fig. 4).

The obtained results show that the maximum throughput increase is in QPSK ½ modulation zone.

Instant throughput increase is in QPSK ½ zone when deploying RS. Accordingly in QPSK ¾ throughput increase is only after 22% RS distance form BS and 16QAM ½ throughput increase is only after 27% RS in those zones. This is because QPSK ½ zone is furthest from the BS.

802.16j network simulation was carried out by changing the frame duration from 10 ms to 20 ms in order to analyze the impact of transmitted signal to the network throughput. Simulation consisted of one base station, one relay station and 40 subscriber stations. Simulation was carried out in QPSK ½ zone, because in this area there is largest throughput increase using relay station. Subscriber stations received data, but didn‘t send any. Influence of subscriber stations number to the slot load in one frame is shown in Fig. 5.

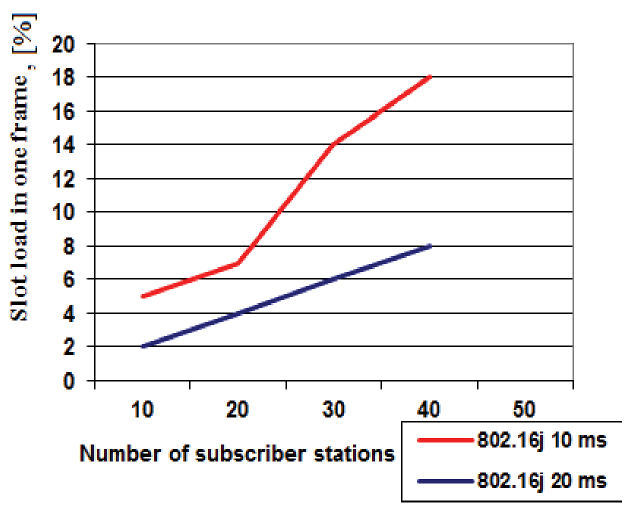

Fig. 5. Number of subscriber stations and slot load in one frame

Using a 10 ms frame transfer rate, with 40 affiliated subscriber stations, slot load in one frame increases by 8%. Using a 20 ms frame rate slot load in one frame increases by 18%. This increase is due that in order to transmit information base station uses more resources in access and retransmission areas.

Subscriber stations number impact to the network throughput was investigated and its dependence is shown in Fig. 6.

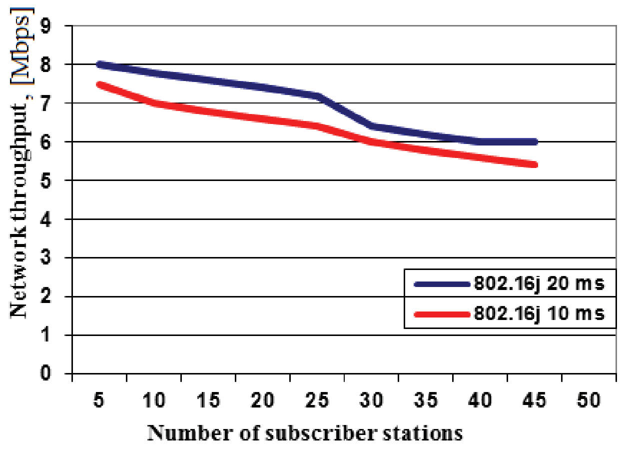

Fig. 6. Number of subscriber stations and network throughput

Using a 10 ms frame transfer rate, when 40 subscriber stations connected to the network, throughput drops from 7.5 Mbps to 5.2 Mbps. Network throughput decreases by 30%. Using 20 ms frame rate throughput drops from 8 Mbps to 6 Mbps. Network throughput decreases by 25%.

Network throughput decreases proportionally with the increasing slot load in one frame.

Impact of relay stations to network throughput with 40 connected subscribers stations that were randomly deployed in the base stations coverage area regardless of modulation zones in which subscriber stations will operate. Fig. 7 shows relay stations impact to the network throughput.

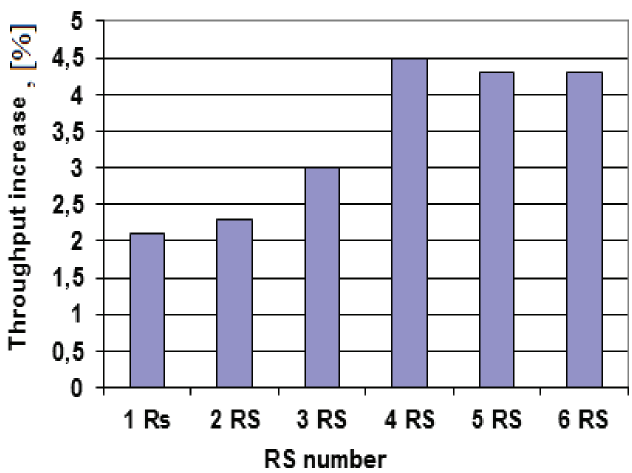

Fig. 7. RS number and throughput increase

Connecting 4 relay stations to one base has the most efficiency, because then the network throughput rate stabilizes. This happens because when using four relay stations they cover the whole territory of the base station. Installing more relay stations there is no data transfer rate increase.

Conclusions

After simulation with NCTUNs, the results shows that the maximum throughput increase is in QPSK½ modulation zone. Deploying RS in that zone throughput rate increases to 25%. When relay station operational in QPSK¾ zone, by changing the position of relay station throughput increases up to 7.2%.When relay station is operational in 16QAM½ zone throughput increases up to 5%.

Instant throughput increase is in QPSK ½ zone when deploying RS. Accordingly in QPSK ¾ throughput increase is only after 22% RS distance form BS and 16QAM ½ throughput increase is only after 27% RS in those zones. This is because QPSK ½ zone is furthest from the BS.

Using a 10 ms frame transfer rate, with 40 affiliated subscriber stations, slot load in one frame increases by 8%. Using a 20 ms frame rate slot load in one frame increases by 18%.

Using a 10 ms frame transfer rate, when 40 subscriber stations connected to the network, throughput drops from 7.5 Mbps to 5.2 Mbps. Network throughput decreases by 30%. Using 20 ms frame rate throughput drops from 8 Mbps to 6 Mbps. Network throughput decreases by 25%.

Network throughput decreases proportionally with the increasing slot load in one frame.

Connecting 4 relay stations to one base has the most efficiency, because then network throughput rate stabilizes. This happens because when using four relay stations they cover the whole territory of the base station. Installing more relay stations there is no data transfer rate increase.

Acknowledgements

The authors would like to thank project MOBAS „The development of information environment for mobile and wireless services" (Nature and technology science committee at the Lithuanian Science Council, Nr. AUT-03/2010) for the support while writing the manuscript.

References

1. **Park W. H., Bahk S.** Resource management policies for fixed relays in cellurar networks // Computer Communications. – Elsevier, 2009. – No. 32. – P. 703–711.
2. **Kajackas A.**, **Rainys R.** Internet Infrastructure Topology Assessment // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 7(103). – P. 91–94.
3. **Awad K. K., Shen X. S., Zogheib B.** Ergodic mutual information of OFDMA – based Selection – Decode – and – Forward cooperative relay networks with imperfect CSI // Physical Communication. – Elsevier, 2009. – No. 2. – P. 184–193.
4. **Wang W., Guo Z., Cai J., Shen X. S., Chen S.** Multiple frequency reuse schemes in the two–hop IEEE 802.16j wireless relay networks with asymmetrical topology // Computer Communications. – Elsevier, 2009. – No. 32. – P. 1298–1305.
5. **Nuaymi, L.** WiMAX – Technology for Broadband Wireless Access. – John Wiley and Sons Publication, 2007. – 286 p.
6. **Wang S. Y., Chen H. Y., Chuang S. W.,** Computer Science Research and Technology. – Nova Science Publishers, Inc., 2011. – 323 p.
7. **Wang S. Y., Chou C. L., Lin, C. C.** The Design and Implementation of the NCTUns Network Simulation Engine // Simulation Modeling Practice and Theory, 2007. – No. 15. – P. 57–81.
8. **Wang S. Y., Chou C. L.** NCTUns Tool for Wireless Vehicular Communication Network Researches // Simulation Modeling Practice and Theory, 2009. – Vol. 17. – No. 7. – P. 1211–1226.
9. **Abhayawardhana V. S., Wassell I. J., Crosby D., Sellars M. P., Brown M. G.** Comparison of empirical propagation path loss models for fixed wireless access systems // Vehicular Technology Conference, 2005. – Vol. 1. – P. 73–77.
10. **Eira J. P., Rodrigues A. J.** Analysis of WiMAX data rate performance // Lisbon: Instituto de Telecomunicaçǿes/Instituto Superior, Technical University of Lisbon, 2009.

Received 2011 02 12

V. Bulbenkiene, V. Pareigis, A. Andziulis, M. Kurmis, S. Jakovlev. Simulation of IEEE 802.16j Mobile WiMAX Relay Network to Determine the Most Efficient Zone to Deploy Relay Station // Electronics and Electrical Engineering. – Kaunas: Technologija, 2011. – No. 6(112). – P. 81–84.

An IEEE 802.16j mobile WiMAX relay network is a next-generation mobile wireless broadband network that uses adaptive modulation coding. When a mobile station is shadowed by a building and thus has a bad-quality channel to the base station, such a relay design can help it achieve a higher throughput from/to the base station. It's not known what modulation zone QPSK½, QPSK¾ or 16QAM½ it should be from base station to relay station to achieve better throughput. Simulation was made with NCTUns. This paper analyzes which modulation zone is most efficient for relay stations to be deployed to achieve maximum network throughput. The number of subscriber stations impact to the network throughput with slot load in one frame and optimal relay stations number connected to one base station. Ill. 7, bibl. 10, tabl. 3 (in English; abstracts in English and Lithuanian).

V. Bulbenkienė, V. Pareigis, A. Andziulis, M. Kurmis, S. Jakovlev. IEEE 802.16j mobiliojo WiMAX imitacija siekiant nustatyti našiausias moduliacijos zonas retransliacijos stotims statyti // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 6(112). – P. 81–84.

IEEE 802.16j mobilusis WiMAX retransliacijos stočių tinklas yra naujos kartos mobilusis plačiajuostis belaidis tinklas, naudojantis adaptyviąją moduliaciją. Jei mobiliąją stotį uždengia pastatai, tuomet, panaudojus retransliacijos stotis, galima pasiekti didesnį tinklo pralaidumą nuo/iki bazinės stoties. Darbe, atlikus imitaciją su NCTUns, analizuojama, kurioje moduliacijos zonoje nuo bazinės stoties reikia statyti retransliacijos stotis, norint pasiekti maksimalų tinklo pralaidumą. Siekiant užtikrinti aukščiausios kokybės interneto ryšį, buvo išanalizuotas abonentų skaičiaus poveikis tinklo pralaidumui, bei plyšių užimtumas kadre, taip pat nustatytas optimalus prie vienos bazinės stoties prijungtų retransliacijos stočių skaičius. Il. 7, bibl. 10, lent. 3 (anglų kalba; santraukos anglų ir lietuvių k.).