Marcin Sokół
Gdansk University of Technology,
Faculty of Electronics, Telecommunications and Informatics,
Department of Radiocommunication Systems and Networks

THE ROLE AND IMPORTANCE OF WIMAX MOBILE SYSTEM AS A HIGH-PERFORMANCE DATA TRANSFER TECHNOLOGY IN WIRELESS SENSOR NETWORKS FOR WIDE AREA MONITORING APPLICATIONS

Abstract: The study discuses basic features and functional design of WiMAX Mobile system, based on the IEEE 802.16e (Release 1.5 Rev. 2.0) standard. The analysis has been made in terms of ability to use this system to transmit video stream related to monitoring of large agglomeration areas. What is more, the study includes comparison of technical parameters of WiMAX Mobile system with competitive systems such as: HSPA+ and UMTS-LTE, which may be used for transmission of this type of data in the future. There has also been made an analysis of selected aspects of data security (in the system approach) connected with transmitting of image data by the WiMAX Mobile networks.
Keywords: HSPA, UMTS/UMTS-LTE, WiMAX Mobile, WSN

1. INTRODUCTION

Video monitoring systems are used to transmit and archive video streams associated with observation of various types of objects in selected geographic area. In the study specially large attention will be dedicated to issue of transmitting this type of data by the metropolitan networks based on WiMAX Mobile system *(Worldwide Interoperability for Microwave Access)*. CCTV monitoring of cities creates extremely wide possibilities of crimes and offences detection as soon as the moment of its committing. Studies which has been made on the issue clearly show that in areas of cities covered with monitoring, the number of assaults, theft or property devastation has been significantly decreased. In case of roads monitoring compliance with traffic rules increases.

Sensor networks can consist of many various types of sensors, for example: seismic, thermal, acoustic or equipped with video camera. Such variety of sensors types results with

their ability to perform their functions in various conditions and control many different factors. Wireless Sensor Networks (WSN) are increasingly used in so called intelligent transport. It is associated, most of all, with the process of traffic monitoring which is realized by transmission of video image gained, in individual nodes of network, to the central unit, where processing, analysis and if necessary archivization of the image is performed. What is more, current level of techniques allows automatic speed measurement of cars on the roads basing on the recorded video.

2. BASIC FEATURES AND ASSUMPTIONS OF WIRELESS SENSOR NETWORKS

WSN networks consist of spatially arranged autonomic sensors, which perform monitoring of environment condition and recording the state of various physical phenomena. The development of WSN networks has been originally dictated by military applications. Currently it is also used in public solutions, especially in industrial monitoring processes and the control of working devices, environment, surroundings, traffic and many other segments of economy. **Requirements for WSN networks:**
- ease and speed of installation,
- ease of management and reconfiguration
- and the transmission efficiency as well as reliability of the data acquired.

Modern WSN networks use for data transmission mainly public Internet and wireless networks for supporting packet data (local, cellular or metropolitan). In such networks, each network node is typically equipped with a wireless module for communication (e.g.: modem or wireless router).

In practice, maximum possible to archive distances of transmission, between network's node and WiMAX base station varies between 5 and 10 km. Large number of used monitoring systems base on data transmission by one or several from following technologies: HSPA *(High-Speed Packet Access)*, UMTS *(Universal Mobile Telecommunications System)*, EDGE (*Enhanced Data rates for GSM Evolution)* or GPRS *(General Packet Radio Service)*. **Type of used data transmission technology is directly associated with maximum speed of transmission and as a result, quality of video image. However it should be noted that speeds of data transmission provided by the WiMAX Mobile system, are the largest in this case (tab. 1, tab. 2).**

It should also be noted that WSN networks using metropolitan networks based on WiMAX family standards, except unquestionable valor have some limitations. They mainly concern the power of the signal which is broadcasted by base stations and as a result the range of each station's performance.

3. WIRELESS SENSOR NETWORKS BASED ON WIMAX MOBILE TECHNOLOGY

Due to different uses of sensor networks, we can distinguish several types of wireless data standards that they use.

Depending on the characteristics of the networks' work, they can be divided into:

- ***Wireless Metropolitan Area Networks (WMAN)*,**
- ***Wireless Local Area Networks (WLAN)*,**
- ***Wireless Personal Area Networks (WPAN)*.**

This paper will discuss only the WSN network based on Mobile WiMAX technology, which is representative of WMAN networks. Over the past few years, this system has gained the status of the leading broadband data transmission system in large metropolitan areas. This is primarily due to the extremely high scalability of the system and performance speeds in both directions of transmission. In particular, however, the transmission speed in the direction of the uplink (UL), directly determines the possibility of using the technology of data transmission in CCTV monitoring systems. WiMAX Mobile standard is dynamically evolving, not only in Europe but also on all other continents. The undisputed attribute of WiMAX systems, is primarily a high transmission efficiency ratio in comparison to the price of its implementation. The costs of implementing in large metropolitan area are significantly lower than wired solutions based on xDSL technology *(Digital Subscriber Line)*, which also do not provide mobility in access to services.

MAC layer *(Media Access Control)* Mobile WiMAX system supports the connection point-to-multipoint, with optional mesh topology for frequencies below 11GHz. For data transmission in the downlink direction (DL) system uses time multiplex TDD *(Time Division Duplex)*. Transmission in the UL direction uses TDMA technology *(Time Division Multiple Access)*. In mode of net topology, all of WiMAX base stations are directly connected to the neighboring stations. WiMAX Mobile system can achieve throughput up to 75Mbps under certain conditions for a distance of 3-10 km from the transmitter base station in the direction of DL and 25Mbps in the direction of UL. Specification of WiMAX Mobile introduces many innovations in the construction of the physical layer (PHY) and MAC. Innovative WiMAX Mobile system determines the growing popularity of this system in the context of its use in the areas of monitoring systems, both high-and low-urbanized areas.

Here are some examples of innovative solutions that are used in PHY and MAC layers of WiMAX Mobile, which make it particularly attractive solution for CCTV wide area monitoring systems:

- **the use of a scalable method of access OFDM *(Orthogonal Frequency Division Multiplexing)* to enhance system performance** in urban environments with multi-way propagation, where there is no direct visibility of antennas (LOS, *Line-of-sight*). The interesting fact is that in using in WiMAX Mobile so-called Scalable OFDM Access (SOFDMA, *Scalable Orthogonal Frequency Division Multiple Access*), which develops flexibility of the possibilities of control channel bandwidth in the range of 1.25 to 20 MHz. Mobile Technical Group (MTG) in WiMAX Forum organization is

engaged in the separation of profiles that clearly identify the elements necessary to build the system in a given environment. Using the profiles provide a choice of network optimization due to capacitive and distributional aspects. At the moment, WiMAX Mobile profiles contain channels with width of 5, 7, 8.75 MHz and licensed frequency bands 2.3, 2.5 GHz.

- **efficient use of MIMO technology** *(Multiple Input Multiple Output)* in conjunction with an innovative method to create subchannels by grouping subcarriers (called subchannelization) and advanced coding and modulation. These innovative solutions allow reconciling the relation of space-time-frequency radio interface system for WiMAX.
- **QoS *(Quality of Service)*,** can not be circumvented by any modern broadband transmission standard. In the WiMAX Mobile system, we can not only implement DiffServ *(Differentiated Services)* algorithms, but also create labels MPLS *(Multiprotocol Label Switching)*, which allow providing QoS end-to-end,
- **scalability of the system**, which determines the potential for further development and popularization of WiMAX. The variable width of the channel (from 1.25 to 20 MHz) allows rational managing the possessed bandwidth and ensuring the right proportions for users in different environments (urban - a highly urbanized, or for example rural - low-urban),
- **security of services,** which in the XXI century, plays a major role for the potential uses of the system. Authorization based on EAP protocol *(Extensible Authentication Protocol)*, encrypting basing on AES *(Advanced Encryption Standard)* algorithm as well as protection of information by CMAC (*Cipher-based MAC*) and HMAC *(keyed-Hash Message Authentication Code)*, are very safe mechanisms of ensuring data security, from the cryptographic point of view,
- **mobility**, which in the WiMAX system is implemented with proper care for the comfort of the user. It is worth emphasizing excellent support from the WiMAX for VOIP technology *(Voice over Internet Protocol)*, enabling transmission of speech signals using Internet connections, which offer WiMAX delay of less than 50 ms.

Technical specifications of WiMAX Mobile system make it very attractive from the streaming video point of view. Broadcast of video stream from cameras installed in the urban areas through a WiMAX Mobile network ensures fast and reliable link quality. After analyzing the development trends of WiMAX family systems, it should be emphasized that this system develops extremely fast in relation to the growing requirements of users. Observing the current situation in the telecommunications market, it appears that demand for bandwidth on the subscriber link (access) will grow at a much lesser extent than in the backbone network alone. It is assumed that the speed of 4Mbps data rate, is usually sufficient for streaming high quality video stream. The main problem, however, lies in the fact that we have no guarantee that this rate will be obtained in the whole network.

4. COMPARING WIMAX MOBILE, UMTS-LTE AND HSPA+ FOR WIDE AREA MONITORING APPLICATIONS

In tab. 1 and below the comparison of the technical parameters of WiMAX Mobile and UMTS-LTE has been summarized.

Tab. 1. Comparison of WiMAX Mobile and UMTS-LTE technical parameters (source: [8]).

Type of parameter:	**UMTS-LTE:**	**WiMAX Mobile (Rel. 1.5 rev. 2)**
Duplex	FDD TDD	FDD TDD
Frequency band for performance analysis	2000MHz	2500MHz
Channel bandwidth	up to 20MHz	up to 20MHz
Downlink	OFDMA	OFDMA
Uplink	SC-FDMA	OFDMA
DL spectral efficiency	1.57bps/Hz/sector (MIMO 2x2)	1.59bps/Hz/sector (MIMO 2x2)
UL spectral efficiency	0.64bps/Hz/sector (SIMO 1x2)	0.99bps/Hz/sector (SIMO 1x2)
Mobility support	max. 350 km/h (target)	max. 120km/h
Frame size	1msec	5msec
HARQ	yes	yes
Link Budget	Typically limited by mobile device	Chase combining
Advanced antenna support	DL: 2x2, 2x4, 4x2, 4x4 UL: 1x2, 1x4, 2x2, 2x4	DL: 2x2, 2x4, 4x2, 4x4 UL: 1x2, 1x4, 2x2, 2x4

Conclusions:
- WiMAX Mobile Release 1.5 and LTE have comparable performance,
- both use OFDMA in the DL with higher order modulation and coding,
- peak performance is similar for same modulation and code rate,
- both support FDD and TDD with channel BWs up to 20 MHz,
- both support higher order MIMO antenna solutions,

- both offer reduced latency,
- a flat end-to-ene network architecture optimized for high speed data,
- throughput and spectral efficiency target for Mobile WiMAX Release 2.0 will further,
- comparable investment to upgrade 2G/3G network to LTE or WiMAX Mobile,
- new spectrum required for either LTE or WiMAX to support wider channel BW.

Market positioning for WiMAX and UMTS-LTE technologies faces a number of factors, more or less objective. Observing the current situation in the telecommunications market shows that business strategies are sometimes more important than technology. Therefore both technologies (Mobile WiMAX and UMTS-LTE) are very similar in a technical sense. The situation is different when it comes to the stage of development of individual systems. The author [12] notes that: *"over 500 large WiMAX networks already operating around the world and over 400 companies supporting this technology undoubtedly created a great advantage over LTE networks, which practically do not yet exist. Of course, clients play here a decisive role, since they take the decision on the selection of future technologies. "*

In tab. 2 and below comparison of the technical parameters of WiMAX Mobile and HSPA + has been summarized.

Tab. 2. Comparison of WiMAX Mobile and HSPA+ technical parameters (source: [8]).

Type of parameter:	**HSPA+**			**WiMAX Mobile**	
	Rel. 7		**Rel. 8**	**Rel. 1.5 rev. 2**	
Frequency	2000MHz			2500MHz	
Duplex	FDD			FDD	TDD
Channel bandwidth	2x5MHz			2x5MHz	10MHz
BS antenna	SIMO 1x2	MIMO 2x2		MIMO 2x2	
MS antenna	1xSIMO			1x2 SIMO	
DL mod-coding	64QAM-5/6	16QAM-3/4	16QAM-5/6	64QAM-5/6	
UL mod-coding	16QAM-3/4			64QAM-5/6	
DL peak user rate	17.5Mbps	21Mbps	35Mbps	36Mbps	48Mbps
UL peak user rate	8.3Mbps	8.3Mbps	8.3Mbps	17Mbps	24Mbps

Conclusions:
- WiMAX Mobile Release 1.5 has comparable peak DL performance for the same Modulation, Coding and Channel BW as HSPA Release 8,
- **WiMAX Mobile Release 1.5 has 2 times better peak UL performance,**
- HSPA+ is constrained to 2 x 5 MHz channels in traditional 3G spectrum assignments,

- WiMAX Mobile Release 1.5 supports channel BWs up to 20 MHz, FDD/TDD and has planned profiles in 700, 1700, 2300, 2500 and 3500 MHz frequency bands,
- WiMAX Mobile provides a flat All-IP end-to-end network.

5. SELECTED DATA SECURITY ASPECTS IN NETWORKS BASED ON WIMAX MOBILE STANDARD

The requirements for networks designed to transmit video data in the area of security are particularly stringent.

The PHY layer of WiMAX Mobile, located below the MAC layer may be vulnerable to so-called jamming and scrambling. Jamming can be very easily detected by the system operator, which creates opportunities to take action to counter this threat. From a technical point of view, much more disruptive and dangerous for the users may be scrambling system, consisting of partial jamming of radio channel. Both of these types of assaults, despite the fact that both represent major technological challenge for those carrying out the attack, could lead to an effective DoS attack *(Denial of Service)*.

The security sublayer defined by the IEEE 802.16e Release 1.5 standard applies only to data link layer security. Authentication and authorization of link layer ensures that the access to the network is granted only to users. Privacy and protection of data traffic from eavesdropping by unauthorized persons is provided by link encryption. Firewalls and AAA *(Authentication Authorization Accounting)* servers are the measures which allow the protection of network layer from malicious attacks. The most widely used protocol for AAA interactions is RADIUS *(Remote Authentication Dial In User Service)*. WiMAX network architecture addresses the application of these techniques for providing secure roaming based on AAA model.

But it is important that solutions implemented in the application layer of video monitoring systems for security do not hamper or in extreme cases do not completely prevent the work of its users. In these types of systems (regardless of used base technology), it is important to identify policy and security architecture that achieve, as far as possible, sometimes difficult balance between optimized work efficiency and the required level of security. **All proposed cryptographic security mechanisms that will apply in these types of systems should be completely open.** It is not recommended to use the copyright/dedicated algorithms and security protocols, because according to the Kerckhoffs' principle such action could measurably reduce the level of the entire system's security.

In the past, security vulnerabilities in the implementation of security were well publicized. The IEEE 802.16e Release 1.5 standard set out a comprehensive set of solutions by using the gained experience. Hardware manufacturers, systems integrators and network operators should cooperate in order to implement network-wide security network suitable for the network.

At present there is no information about effectively carried out attacks on networks based on WiMAX Mobile system. Most of presented assaults are purely academic and indicates the potential susceptibility of WiMAX.

6. CONCLUSION

This study was entirely devoted to discussing the role of WiMAX Mobile system in modern wide area monitoring systems.

Concluding, it should be noted that the WiMAX Mobile system is a very attractive solution in the context of its possible uses for transferring high resolution video images. Both the technical parameters of the system and the number of research projects supported by the European Union in this area suggest that over the next few years, the role and importance of metropolitan networks will grow rapidly.

References

1. Gajewski S.: *Future-Oriented Directions of Research on New Generation Cellular Technologies and System Application Solutions* (in Polish). Przeglad Telekomunikacyjny i Wiadomosci Telekomunikacyjne, no. 2-3/2010, Poland, **2010.**
2. Rutkowski D., Sokół M., *Data security in IPsec VPN network based on AES-Rijndael cipher* (in Polish), Krajowa Konferencja Automatyzacji i Eksploatacji Systemów Sterownia i Łączności, Jurata **2009**.
3. Sokół M., *Security of All-IP core network in the UMTS cellular system* (in Polish), IV Krakowska Konferencja Młodych Uczonych, Kraków **2009**.
4. Pieprzyk J., et al., *Fundamentals of Computer Security*, Springer-Verlang Berlin Heidelberg, **2003**.
5. Microsoft Corp., *Assessing Network Security*, Microsoft Press, **2005**.
6. Menezes A.J., Oorschot P.C., et al., *Handbook of applied cryptography*, CRC Press LLC, **1997**.
7. Anderson R.J., *Security engineering: a guide to building dependable distributed system*, John Wiley and Sons Inc., **2001**.
8. Gray D., *Comparing Mobile WiMAX with HSPA+, LTE, and Meeting the Goals of IMT Advanced,* Presentation for Orlando MWG F2F, **2009**.
9. Collective work, *Mobile WiMAX Security (Research papers of Airspan Networks Inc.)*, **2009**.
10. Katz M.D., Fitzek F.H., *WiMAX Evolution. Emerging technologies and Applications*, Wiley and Sons, **2009**.
11. Chen K-C., Marca J.R., *Mobile WiMAX*, Wiley and Sons, **2009**.
12. Ahson S., Ilyas M., *WiMAX. Technologies, Performance Analysis and QoS*, CRC Press, **2008**.
13. Karczewski M., *WiMAX i LTE – jedno i to samo*, source: www.netfocus.pl, **2010**.

ROLA I ZNACZENIE SYSTEMU WIMAX MOBILE JAKO WYSOKOWYDAJNOŚCIOWEJ TECHNOLOGII TRANSMISJI DANYCH W BEZPRZEWODOWYCH SIECIACH SENSOROWYCH DO MONITOROWANIA ROZLEGŁYCH OBSZARÓW

Streszczenie: W pracy omówiono podstawowe cechy i założenia funkcjonalne systemu WiMAX Mobile, opartego na standardzie IEEE 802.16e Release 1.5 Rev. 2.0. Analizy dokonano w kontekście możliwości wykorzystania tegoż systemu do przesyłania strumieni wideo związanych z monitoringiem obszarów dużych aglomeracji. Dokonano ponadto porównania parametrów technicznych systemu WiMAX Mobile z konkurencyjnymi technologiami transmisji danych takimi jak: HSPA+ oraz UMTS-LTE, które również mogą być przyszłości wykorzystane do transmisji tego typu danych. Przeprowadzono także analizę wybranych aspektów bezpieczeństwa danych (w ujęciu systemowym) związanych z przesyłaniem danych obrazowych za pośrednictwem sieci WiMAX Mobile.

Słowa kluczowe: HSPA, UMTS/UMTS-LTE, WiMAX Mobile, WSN.