WIRELESS METROPOLITAN AREA NETWORKS FOR TELEMONITORING APPLICATIONS

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Abstract: Wireless Local area networks (wLANs), particularly from standards 802.11b/g, have become extremely widespread in a very short time, in society in general as well as at an industrial level. One of the limitations of this technology is its coverage. The family of new standards, such as 802.16, allows us to overcome these limitations, enabling then their use as Metropolitan Area Networks (MAN), as required by some application domains of industrial networks. In the present work we present an application of this technology in telemonitoring systems on metropolitan areas which shows their potential, but also the complexity of predicting their behaviour in a dynamic scenario such as a large city. *Copyright ©2007 IFAC*

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1. INTRODUCTION

Industrial networks are a well known technology, widely used in different application domains. Since there are different application domains, different solutions can be found, requiring a complex standardization process (Sauter, 2005), not yet finished and in continuous evolution. Its common objectives in all the different application domains are to reduce the cost, increase the flexibility and facilitate maintenance operations. Concerning the common requirements, we can consider that they must provide reliability and timeliness, at different levels that are application dependent. Concerning the traffic characteristics, typically we can consider cyclic traffic, subject to deadlines; the presence of important acyclic packets, such as

alarms, which require a reliable transmission with limited latencies; and also it is assumed that the length of packets are short, in the order of a few bytes.

From the point of view of application domains industrial networks fall into five different categories (Thommesse, 2005). Thus, the requirements of synchronization, distances or time constraints have different levels depending on the application domain: discrete manufacturing, process control or embedded systems. These three application domains belong to the LAN domain. The other two, building automation and control of utilities, belong to the MAN domain. In the building automation area the applications are more relevant to data acquisition and supervision than to control, this being often very simple. There is more extended use here, with the typical state information, of multimedia streams. Another difference

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Table 1. WMAN and WWAN Standards

	802.16.d (802.14-2004)	802.16e (802.16-2005)	802.20	802.22
Fixed Access	yes	yes	yes	yes
Full Mobility	no	yes	yes	no
Node velocity (kmph)		<60	<250	
Frequency bands (GHz)	2-11 (NLOS)	2-6 ¹	<3.5	54-862 MHz
Year	2004	2005	2007-08	2008
cell size (km)	<4 (NLOS)	1 ²	>15	20-40
data rates (Mbps)	36-135	30	16	18
	OFDM & OFDMA	OFDMA		

¹, ², ³ and ⁴ 2.5GHz the band used in the *mobility profile*.

is the use of a higher number of devices and controllers, which makes them very complex systems. Reliability is also required, but with lower demand. In the control of utilities the applications consist of remote monitoring and control of very large networks for the distribution of water, gas, or electricity. The networks are no longer really LANs, as the operators are in central control rooms for operation and maintenance organization. The traffic consists of status variables and events, the data rate depending on the complexity of the system considered. The networks have the same dependability roles as a fieldbus in a factory, the difference being in the distances covered. For example, power line protocols are used in electrical networks, radio waves are often used to connect very remote stations, and it is also now a preferred domain for Internet use.

On the other hand, the use of wireless in industrial networks is currently a promising research area (Sauter, 2005)(Willing *et al.*, 2005)(F. De-Pellegrini, 2006). However the use of this technology for industrial communications is complex due to the properties of radio channels, making it more difficult to meet the reliability and timeliness requirements.

In this paper we present the experimental results obtained in a telemonitoring MAN application using WiMAX technology. In the next section, a brief description of these technologies is given. In section 3 the scenario in which it is applied is described, and in section 4 the experiments performed, ending the paper with the conclusions.

2. WiMAX

WiMAX activities started in August 1998, and it was the IEEE 802 group who led the formation of the Working Group 802.16 Broadband Wireless Access (BWA) Standards in 1999. The necessity of NLOS (*Non Line of Sight*) links moves the frequency bands from 10-66 GHz to 2-11 GHz. The standardization of 802.16e in 2005 adds mobility support to the family (SenzaFiliConsulting, 2005). Other standards that will be a choice in the future

for this kind of application will be IEEE 802.22 Wireless Regional Area Network or IEEE 802.20. The current standardization process and their different characteristics are summarized in table 1.

IEEE 802.16 is optimized for point to multipoint (PTMP) configurations, where there is a base station (BS) and several subscriber stations (SS). Of these three air interfaces, the OFDM³ is suitable for NLOS and is the more extended due to a lower peak to average ratio, faster FFT⁴ calculation, and less stringent requirements for frequency synchronization compared to OFDMA⁵ (A. Ghosh, 2005). It offers a flexible burst-type frame structure with fixed frame duration, and the duplexing is provided by means of TDD⁶.

3. SCENARIO

The water purification network of a large city has different water management centres distributed throughout the city. In these stations there generally exists a PLC⁷ connected to different distributed peripheral devices, functioning autonomously. Therefore it is a two level architecture, where WiMAX is only used as a backbone network for management purposes (W. Granzer, 2006). The need to include multimedia information is forcing the gradual elimination of radio 2400bps communication and the inclusion of more appropriate technologies for the needs of this system, enabling a more globally consistent view of the system in the management level. It is, therefore, an industrial network application that can be considered a combination of control of utilities networks and a building automation application.

In fig. 1 we can see the WiMAX stations distribution in our MAN scenario. Station 1 is connected through a point to point (PTP) LOS link directly with C, which is the central station. Station 2 uses also a PTP link, but NLOS, to communicate

³ orthogonal-frequency division multiplexing

⁴ Fast Fourier Transform

⁵ Orthogonal Frequency Division Multiple Access

⁶ Time division multiplexing

⁷ Programmable Logic Controller

Fig. 1. WiMAX station distribution

with station 3, which acts as a repeater. The BS of the PTMP nodes is in station 4, and their SS are C (LOS), station 3 (LOS) and station 5 (NLOS), so station 4 acts as a repeater for the communications between stations 3 and 5 with C.

4. EVALUATION OF WIMAX LINKS

The WiMAX connections between C and remote stations were made using BreezeNet equipment made by Alvarion (satisfies rule 15 of FCC and ETSI EN 301 489-1 (ETSI, 2005-06)). The equipment works in the test in TDD mode, with OFDM modulation and FEC error correction, with adaptive modulation with channels of 10MHz, and in the band 5.4 (5.470-5725 GHz). The channel evaluation was done with the system operating in the field, for which little additional traffic was inserted to interfere as little as possible. We measured the channel behaviour from the application point of view, and made preliminary measurements of the channel characterization.

In our scenario, the transmission using radio 2400 bps is considered *out* when this is out for 1 minute, which triggers the appropriate response. So to analyze this we send pings, with a periodicity of 2 seconds, and we consider a cut in the channel where we miss 10 consecutive pings, and remain in this state until the correct transmission of 5 consecutive pings.

In fig.2 we can see the communication cuts in all the links measured over 600 hours (25 days). Note that all the LOS links, both in PTP as in PTMP, have an acceptable behaviour for the application. In particular, the link 4-C only had 4 cuts in the same day, none of them higher than 35 seconds, or the link 1-C, where only one cut, of 62 seconds, was recorded, or the worst 3-4-C, where in the

Fig. 2. Communication burst

same day cuts of 81, 151 and 656 seconds were produced.

The NLOS links showed a significantly worse behaviour, especially in the link with station 2, which has the bigger distance. In the link 5-4-C we can see some bursts reaching around 1000 sec. Thus, between 17/02 and 26/02 no losses were produced, but on this day errors up to 4000 sec. were produced. Between the bursts of 9/02 and 13/02, one loss was recorded on 10/02 and another on 13/02, both negligible. The link with station 2 showed a much higher number of bursts, and with cuts of longer duration, exceeding 10k sec.

Table 2. PER for T=1000 msec.

bytes	1	3	4	5
1000	0.002% ³	0.004% ¹	0.003% ¹	0.20% ¹
100	0.033% ²	0.003% ²	0.004% ²	0.0147% ²

¹: 200.000 packets. ²: 100.000 packets. ³ 40.000 packets.

For the channel characterization we measured the interarrival packet with T=1000 msec, and using packet sizes of 100 and 1000 bytes as well as the packet error rate (PER). In table 2 we can see the PER obtained and the number of packets used to measure it. We can see a more than acceptable behaviour in the PTMP links, especially in the LOS links. In the NLOS links, where the link quality is lower and with many bursts, the size of packet has a strong impact in the PER. In figs. 3 and 4 we can see the histogram of interarrival packet and the respective spread. It is noticeable how stations 3 and 5 have a wide histogram, due to the use of one repeater station which represents one hop, and how the size of messages has a strong influence on the interarrival times.

Fig. 3. Histogram of interarrival times using 100 byte long messages

5. CONCLUSIONS AND FUTURE WORK

The use of WiMAX has a great potential in the application domain analyzed in this work. However, the burst behaviour of wireless networks has to be taken into account. To model the behaviour of this channel is usually a complex task in a controlled environment, but it represents a big problem in a dynamic scenario like a big city. An example of this is the link with station 4, where the first measurements showed the worst behaviour of all stations, and this situation worsens during the test period, being currently a link which needs new adjustments in antennae and configuration.

We plan to extend in time the measurements of the channel links, with different packet sizes and network utilization rates, to characterize the WiMAX channel in different situations, and estimate the channel model (Chaotic Maps, Hidden Markov Models (D. Brevi, 2006)).

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Fig. 4. Histogram of interarrival times using 1000 bytes long messages

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