Wi-Fi Data Services as an alternative for CALM-based ITS solutions

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Abstract: Communication is very important part of Intelligent Transport Systems chain to have reliable and secure data transmission between elements within the ITS architecture. One of the ways to achieve a more reliable ITS applications is to make them independent from the communication and solve this part separately. This is the idea of CALM-based system which covers more access communication solutions. But if there is a necessity to have reliable data transmission, the communications access technology has to be described. This paper focuses on the evaluation of WiFi as suitable communication technology for CALM-based system usage based on laboratory measurement of WiFi properties.

Key-Words: – Intelligent Transport Systems, Telematics, WiFi, Multipath access solution

1 Introduction

Intelligent Transport Systems (ITS) are penetrating more segments of the market and providing more complex services, security solutions included. As an example of applications with high requirements for reliability and security we can introduce eCall or Electronic Fee Collection, where there is necessary to deliver all data without any obscuration or error. That’s the reason why requirements for security and reliability of these solutions are increasing and why we have to focus on it.

On the other hand there is necessary to understand this area in big picture of ITS architecture perspective. This is the reason why we follow ITS architecture.

In our work we focused on telecommunication subsystem which is the part of ITS chain. Results in this paper were obtained within project DOTEK1 performed in e-Ident laboratory2 and present Wi-Fi data services laboratory measurement to verify that the technology is suitable for ITS CALM based system implementation which is described in next chapter. Test methodology, test environment and results are described below.

2 ITS CALM-based system

If more than one wireless telecommunication solution is applied within telematic solution, the family of standards ISO TC204, WG16.1 “Communications Air-interface for Long and Medium range” (CALM) - see [5] - [6], [8] - [10] - represents the concept of identification and selection of the best available wireless access solution in given time and area. Process of the alternative wireless access solution substitution is understood as the second generation of the handover principle known in its first generation namely from the cellular mobile systems. Each handover process is predestinated by set of parameters range identified for decision processes managed by control unit. Criteria for the “best possible” solution do not include only usual performance indicators like Bit Error Rate (BER), packet Round Trip Delay (RTD), level of received radio signal (compared with the other base stations being just available), but also performance indicators identified on the L3 (IP) layer – packet time to deliver or round trip delay, packet loss ratio, delay jitter etc. Another type of parameter to be taken into account is e.g. cost of provided service, company policy etc. Handover activation can be evoked also by identification of more suitable alternative - e.g. by appearance of alternative service with better cost conditions even though existing alternative has been technically sufficient and safe. In addition the management system can take into account not only the absolute values of particular indicators, but also their specific combinations and its trends.

1 DOTEK – Communication module for transport telematics – grant 2A-2TP1/105 of Ministry of Industry and Trade of the Czech Republic (MPO)
2 e-Ident – laboratory for electronic identification and communications established in 2008 in Prague, Czech Republic
In ITS world we can find following communication technologies applied within telematic applications:

- 2G Cellular systems GSM (Global System for Mobile) namely GPRS (General Packet Radio Service) and EDGE (Enhanced Data rates for GSM Evolution),
- 3G Cellular systems UMTS (Universal Mobile Telecommunication System),
- Millimeter wave technology (62-63GHz),
- Satellite communications,
- RC (5.8GHz),
- Mobile Wireless Broadband (MWB) – today namely communications systems based on IEEE 802.16e and coming IEEE 802.20,
- Infra Read (IR) communications,
- WiFi (IEEE 802.11 based) different alternatives - a, b, g, n,
- M5 based on standard IEEE 802.11p,
- IEEE 802.15.x based solutions: Bluetooth – 15.1, Ultra Wide Band (UWB) - 15.3, ZigBee - 15.4,
- W-USB (Wireless USB),
- Other media to come.

### 3 Telematic sub-system requirements

Communications performance indicators must be defined in the way that influence of communications performance indicators is transformable into telematic performance indicators area.

The methodology for the definition and measurement of following individual system parameters is being developed in frame of the ITS architecture (see [1] - [3]):

- **Accuracy** – defined as quality of congruence between measured and defined value of parameter/process/function.
- **Reliability** – defined as system ability to execute required functions without interrupting in defined time interval on certain probability level.
- **Availability** – defined as system ability to execute required functions after system/process initiation according to certain procedure till time limit on certain probability level.
- **Continuity** – defined as system ability to execute required functions/processes without unplanned interrupting (outage) on certain probability level.
- **Integrity** – defined as system ability to diagnose overrun predefined parameters and inform user/operator about this fact after required time interval on certain probability level.
- **Safety** – defined as system ability to ensure that in the case of fault will not come to system damage, material losses or human life losses.

Substantial part of the system parameters analysis is the decomposition of system parameters into individual sub-systems of the telematic chain. This step represents analysis of requirements on individual functions and information linkage so that the whole telematic chain should comply with the above defined system parameters.

The completed decomposition of system parameters enables application of the follow-up analysis of telematic chains according to the various criteria (optimization of the information transfer between a mobile unit and processing centre, maximum use of the existing information and telecommunication infrastructure, etc.). It is obvious that quantification of requirements on relevant telecommunication solutions within telematic chains plays one of key roles in this process. Mobility of the communication solution represents one of the crucial system properties namely in context of frequently very specific demand on availability and security of the solution. Monitoring and management of the airport over-ground traffic was one of our key projects where our own approach to system solution was designed and tested (see [7]). This application is characterized by strict but transparent regulation and successful tests of ITS system under heavy airport conditions and it can be understood as the representative telematic reference.

Following communications performance indicators quantify communications service quality (see e.g. [4]):

- **Availability**
  - Service Activation Time (SAT) – defined as time needed for activation/modification of the network archived on certain probability level.
  - Mean Time to Restore (MTTR) – defined as time service is restored from unexpected inoperable stage on certain probability level.
  - Mean Time Between Failure (MTBF) – defined as time between two unexpected inoperable stages on certain probability level.
  - VC availability – percentage of correctly provided service in appointed time interval on certain probability level.
- **Delays** (latency) – an accumulative parameter defined as time frames are delivered within a defined time period on a certain probability level. This parameter is effected by
  - interfaces rates,
  - links capacity,
  - frame size and
  - load/congestion of all in line active nodes (switches).
- **Packet/Frames Loss** – percentage of undelivered packets/frames within defined time period on certain probability level.
- **Security - Risk Analysis (RA)** and classification must be done based on detailed knowledge of the
system environment and potential risks. Risk of information integrity can be caused by attack on any part of the information transfer chain.

- Signal quality
  - Signal to Noise Ratio (SNR) – SNR expresses distance of signal from noise interference.
  - Received Signal Strength Indication (RSSI) – This value of RSSI indicates absolute value of signal power which is independent of the surrounding (for Wi-Fi is this value so-called user index of the connection signal power).
  - Bit Error Ratio – Parameter BER indicates bit error rate of the data connections within the wireless communications channel. BER = wrong bits / total bits.

As we stated before, communications performance indicators must be defined in the way that influence of communications performance indicators is transformable into telematic performance indicators area.

### 4 Wi-Fi data services performance

As is widely known, Wi-Fi is often used as a cheap, available and sufficient technology for data services. The most common use is as the last mile of internet providers. Use for professional applications such as telematics applications brings us several potential risks. Our study focuses on identifying the position of Wi-Fi in the mentioned CALM-based systems and application in telematic systems. We are trying to classify the technology with dedicated performance indicators, so that it can be used in the CALM-based systems. Some of these dedicated performance indicators were measured in laboratory and the possibility of their use under various conditions was verified. When Wi-Fi is integrated into a CALM-based system, then it is dependent fully on this system, which on the basis of values of measured dedicated performance indicators chooses the most appropriate medium and makes possible handover.

#### 4.1 Measurement methodology

Our measurements were made in a laboratory environment. Unfortunately, due to the wide extension of Wi-Fi technology, it was impossible to achieve radio silence, so measurements were conducted in the presence of signals from other transmitters. To test the connection, the frequency with greatest frequency separation from other transmitters has been chosen. For the measurement we developed our own software, which allows to measure and evaluate parameters of Wi-Fi network automatically. Software was processed using L3 (IP) layer tools. Software was written in Perl and Python and it gains values SNR from operating system of the WiFi client and uses software ping for determination of delay (latency) and packet loss. For each set of measurement were transmitted two different packet sizes (72 bytes and 1308 bytes) in two different access point load (without and with data transfer). In each of these four variants 1000 packets were transmitted – 10 cycles of 100 packets. Value of SNR was changed after these 4000 packets.

For changing SNR value we used adjustable attenuator between Wi-Fi access point and Wi-Fi client, as you can see on a figure 1.

![Fig. 1: Set-up of the technology for the measurement](image)

#### 4.2 Measurement results

Software has recorded the results of individual stages measurements, from which it finally drew up the overall statistics for Wi-Fi technology. The following table is the individual example of partial results of the measurements.

<table>
<thead>
<tr>
<th>Data transfer</th>
<th>without</th>
<th>without</th>
<th>with</th>
<th>With</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packet size [byte]</td>
<td>72</td>
<td>1308</td>
<td>72</td>
<td>1308</td>
</tr>
<tr>
<td>Min</td>
<td>2,57</td>
<td>6,92</td>
<td>313,58</td>
<td>262,34</td>
</tr>
<tr>
<td>Max</td>
<td>16,47</td>
<td>28,77</td>
<td>1322,39</td>
<td>1027,05</td>
</tr>
<tr>
<td>Avg</td>
<td>3,5</td>
<td>10,93</td>
<td>638,83</td>
<td>650,88</td>
</tr>
<tr>
<td>Jitter delay [ms]</td>
<td>avg</td>
<td>1,62</td>
<td>2,97</td>
<td>188,06</td>
</tr>
<tr>
<td>avg</td>
<td>0</td>
<td>0,1</td>
<td>1,4</td>
<td>1,2</td>
</tr>
<tr>
<td>avg</td>
<td>12,1</td>
<td>13,2</td>
<td>11,7</td>
<td>12,5</td>
</tr>
<tr>
<td>avg</td>
<td>21,9</td>
<td>22,5</td>
<td>22,1</td>
<td>22,3</td>
</tr>
<tr>
<td>avg</td>
<td>15,55</td>
<td>16,87</td>
<td>19,89</td>
<td>19,81</td>
</tr>
<tr>
<td>avg</td>
<td>2,19</td>
<td>2,08</td>
<td>1,66</td>
<td>1,7</td>
</tr>
</tbody>
</table>

Table 1: Data from one set of measurement

Table 1 shows example of the results from one set of the measurement. The value of SNR as shown is not constant; it fluctuates around its average because of changing value of ambient noise. In order to see how many values fluctuate, we left the program to calculate the statistical variance of values of SNR. For values of delay, the situation is similar, there are many influences that affect the resulting delays, one of the effects is the change of SNR value. The following graphs were created by our program output.
4.3 Evaluation of test results

We made several measurements for different signal levels, respectively for different SNR. The measurement was several times repeated, so we had enough available data, on which we based their evaluation. The crippled values sometimes occurred among measured data, which was the main reason why we did measurement once more or we discarded whole (one) measured set. Because value of delay is quite variable, we considered average of particular averages. Keep in mind that it is only statistic value and actual value is close to it just in average.

The first graph (Fig. 5) results that for lower SNR values the latency is really higher and between 10 and 20 dB
there is a threshold, where the latency is significantly increased. You can also see on the graph that for higher values of SNR there is almost no difference. We also notice how the packet size influenced its own latency. Small packet with size of 72 bytes was delayed about 3 ms, while the packet with size of 1308 bytes was delayed about 10 ms.

On the second graph (Fig. 6) we see the progress of the latency depending on the SNR in loaded data transmission. Latency for different packet sizes is not very different in this case, but the value of latency is interesting. For load link values of latency goes up to several hundred ms. There we can see a point between 10 and 20 dB, where is a greater increase in latency again.

The last graph (Fig. 7) shows the course of packet loss and SNR. Already we don’t make a difference between small or large packets, but it is necessary to distinguish whether the measurement was without or with data transmission. If a measurement was without data transfer, the values of packet loss were almost zero. During packet transmission there was packet loss at least 1% and again with a decline below 20 dB SNR packet loss is increasing.

General conclusion is that for the SNR values equal to 20 dB and more latency values are constant and vice versa - for values below 20 dB latency values are rising. Latency values depend on the connection load, while during full load can go up to several hundred ms. That’s why in this case the full load plays a greater role then just level of SNR.

The result is that it is not possible to determine appropriate value of latency for the chosen SNR value, because it is also dependent on other parameters such as packet size, current workload of network, etc. At least we can derive quality of connection from gained values. For this we prepared following table.

<table>
<thead>
<tr>
<th>Value of SNR</th>
<th>Number value</th>
<th>Quality</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5 dB</td>
<td>0</td>
<td>no signal, cannot connect</td>
<td></td>
</tr>
<tr>
<td>5 – 15 dB</td>
<td>1</td>
<td>very weak signal, problematic connection, more latency and packet loss</td>
<td></td>
</tr>
<tr>
<td>15 – 20 dB</td>
<td>2</td>
<td>weak signal, still problematic connection, latency and packet loss are still above average</td>
<td></td>
</tr>
<tr>
<td>20 – 30 dB</td>
<td>3</td>
<td>good signal, average speed and latency, low packet loss</td>
<td></td>
</tr>
<tr>
<td>30 – 50 dB</td>
<td>4</td>
<td>very good signal, good data rate, low latency, almost zero packet loss</td>
<td></td>
</tr>
<tr>
<td>&gt; 50 dB</td>
<td>5</td>
<td>excellent signal, high data rate, low latency, zero packet loss</td>
<td></td>
</tr>
</tbody>
</table>

Tab. 2: Summary table of general results

5 Conclusion
Wi-Fi data services are designed to provide services in company and small networks. Due to its expansion the services have problems with interference, but at the same time this opens the possibility of wider use of this technology for non-critical services of ITS.

Our analysis and measurement has shown that appropriate technology has potential use in the ITS field. Currently new version of Wi-Fi – IEEE 802.11p is in development. This version of Wi-Fi will be available in June 2010. Standard IEEE 802.11p wants to eliminate some of discovered problems and with combination with IEEE 802.11r and 802.11e offer the full use of Wi-Fi technology in the field of ITS systems. However, today we can classify some of the parameters and values used to a limited extent for decision making.

Strong potential is so recognized in combination of more data services technologies, for example Wi-Fi, GSM, WiMAX and others. Alternative services are dedicated to fill the services gaps which cannot be provided by the core wireless network (continuously or in critical time periods). Alternative service combination strategy based on CALM principles can effectively extend potential of widely spread Wi-Fi data services applications.

References:
