

Analysis of Wireless Measurement Transmission Performance

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Abstract

The permanent and almost ubiquitous world cellular network can be used for data transmissions for civil/general purposes. The use of data acquisition and data transmission over Public Land Mobile Networks can save time and improve performance with minimum footprint from technology and equipment point of view. Regarded as a cost efficient approach this method has certain benefits. Quality and availability are constantly improved and maximized for data transmission at this moment in time, thus making the solution available for small businesses and/or remote areas. Simulations and measurements with Wellman PCS-500 Digital Oscilloscope provide the data for the conclusions.

I. Introduction

Data transmission over air has increased substantially since the mobile phone spectrum reservation. The always-on availability and the increasing mobility (handover and roaming) provide usability of this communication paradigm to other domains of activities such as remote and on the move measurement. In this study a measurement workbench with stimuli input from an oscilloscope and with real transmission over air is developed. The GSM/GPRS/UMTS network architecture provides the transport. The purpose is to start a study for data transmission in case of remote measurements via **existing operator** infrastructure - Public Land Mobile Networks (see an example in Figure 1), available now to more than 3 billion subscribers worldwide and to test/introduce the concept of **mobile oscilloscope**. In that case the probe and the remote client are both mobile.

II. Objectives

The first objective is to **establish a testing and measurement connection** which is reliable and to **perform several measurements** in order to determine the best method to transmit electrical measurements. The network elements in this case are divided between the network **transport medium** which enables the transmission and the **data acquisition** equipment.

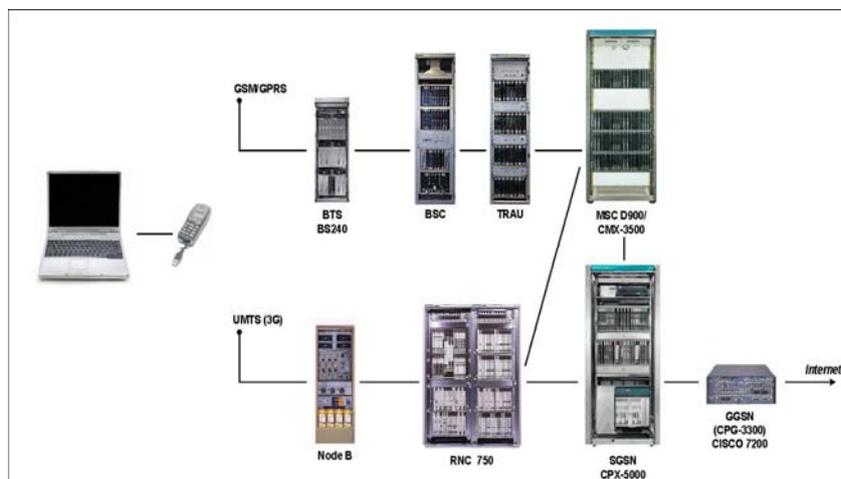


Figure 1. The measurements and study is done in a testing environment. Equipment interconnection (e.g. Siemens <http://www.siemens.com>)

III. Description

The PLMN network is in this case formed of real equipment products starting with core network components: SGSN, MSC (HLR and VLR), GGSN and continuing with the GSM/GPRS Enhanced Radio Access Network. All these components are in a certain degree interconnected. Network processing and air interferences can be the cause for errors. The interfaces used for data transmission cover all the physical range from air (radio waves), to electrical and optical: Uu/Um air interfaces for GSM/GPRS/UMTS even the optical UMTS interfaces Iub, Iu, Iur, continuing over Ethernet electrical/optical Interfaces Gn and Gi. The tests were performed on GPRS/EDGE platform.

Mobile Network

From the radio access point of view, the transmission is Up Link (UL) if it is from the mobile to the network and Down Link (DL) if it is vice-versa. Generally, the network improvements apply first to the DL, in order to enlarge the download bandwidth.

Enhanced Data Rates for GSM Evolution is a bolt-on enhancement of the 2G/2.5 GSM. Data Rates possible for DL are up to 236.8 kbit/s for 4 timeslots (theoretical maximum is 473.6 kbit/s for 8 timeslots) in packet mode. After Context Activation is accepted by the network at the request of the mobile (based on a valid SIM/subscriber) the mobile/subscriber and the laptop attached to it via USB/Bluetooth are able to communicate on the Internet or with other subscribers in the network based on the IP (assigned by the GGSN). At the other end, the station or client (depending on the situation, see Figure 2) is connected on the Gi Interface/Internet.

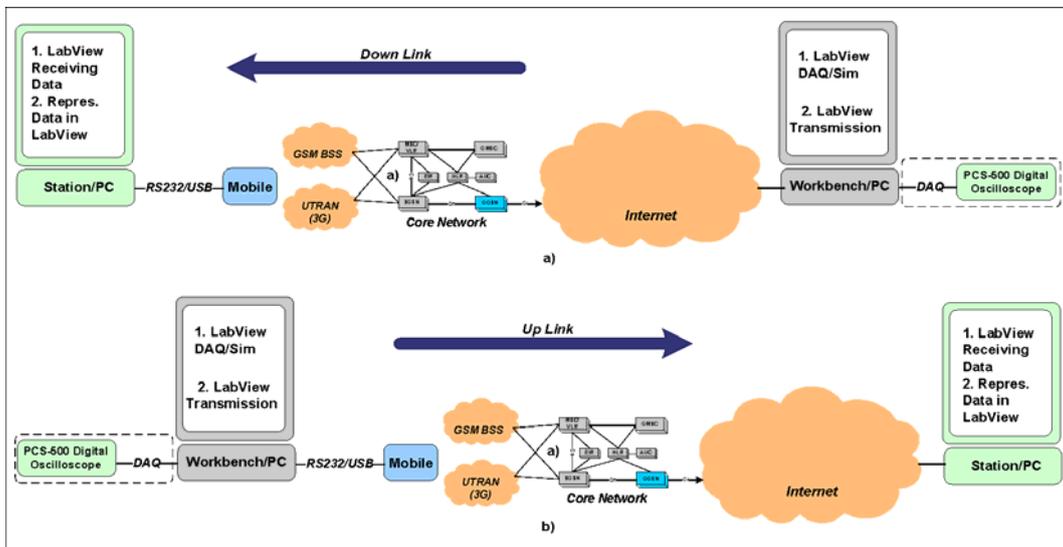


Figure 2. Scenarios for Remote Measurement over PLMN: a) Remote Measurement with DL Transmission; b) Remote Measurement with UL Transmission

The stimuli acquisition/oscilloscope

The stimuli acquisition is done using Velleman Digital Oscilloscope (Velleman PCS-500 Digital Oscilloscope) either on simulated data (in Demo Mode) or with real measurement. The oscilloscope takes a 5000 points sample of the measured or internally simulated signal (Table 1).

Buffer Position	Signification [SI]	Parameter	Tested Values
Position 0	Sample Rate [Hz]	Volts/Div.	0.5, 1.5V
Position 1	Full Scale [mV]	Time/Div.	100ms, 50ms, 20ms, 10ms, 1ms, 0.5ms, 0.2ms, 0.1ms, 50us, 20us, 10us, 5us, 2us, 1us
Position 2	GND		
Position 3...5000	Data		

Table 1. Buffer Information and Oscilloscope Data

Element	Value	Range/Source
Buffer	5000 samples	
Resolution	8 bits	0-255
Sampling Rate	Var.	1250-50.000.000 From Oscilloscope Settings
Number of Samples Transmitted	1000	200-2000 (max. 5000)

Table 2. Sampling and Rate Parameters

Two main rates in data transmission apply: the sampling rate applied to the signal under measurement (Table 2) which leads to the filling of the buffer and the rate at which the buffer is read. These two values must be correlated; the reading of the buffer should not be done earlier than the next storage in the buffer (3).

The actual measurement with the oscilloscope of the signal produces at once 5000 samples stored in I/O memory buffer. The **Sampling Rate** is:

$$SR = \frac{\text{No. of Samples}}{1 \text{ sec}} = 5000 \cdot \text{No. of Readings} / \text{sec} \quad (1)$$

Hence the **Number of Readings**:

$$\text{NoR} / \text{sec} = \frac{SR}{5000} \text{ (Hz)} \quad (2)$$

Which leads to the **Time To Wait** until the buffer is full and can be read again:

$$TTW = \frac{5000}{SR} \text{ (sec)} = \frac{5000 \cdot 1000}{SR} \text{ (msec)} \quad (3)$$

TCP/UDP Transport

The measurements obtained with the oscilloscope are transmitted on top of the Internet Layer (Layer 3 in TCP Stack, Network Layer in OSI Stack) on the Transport Layer. The Transport Layer can use TCP or UDP. The difference between them consists on the acknowledgment of the received packets. TCP works on the basis of sending data as soon as the last send data is positively acknowledged by the receiving party (establishment of end-to-end operations). In UDP, the Datagrams are sent regardless of the successful receiving.

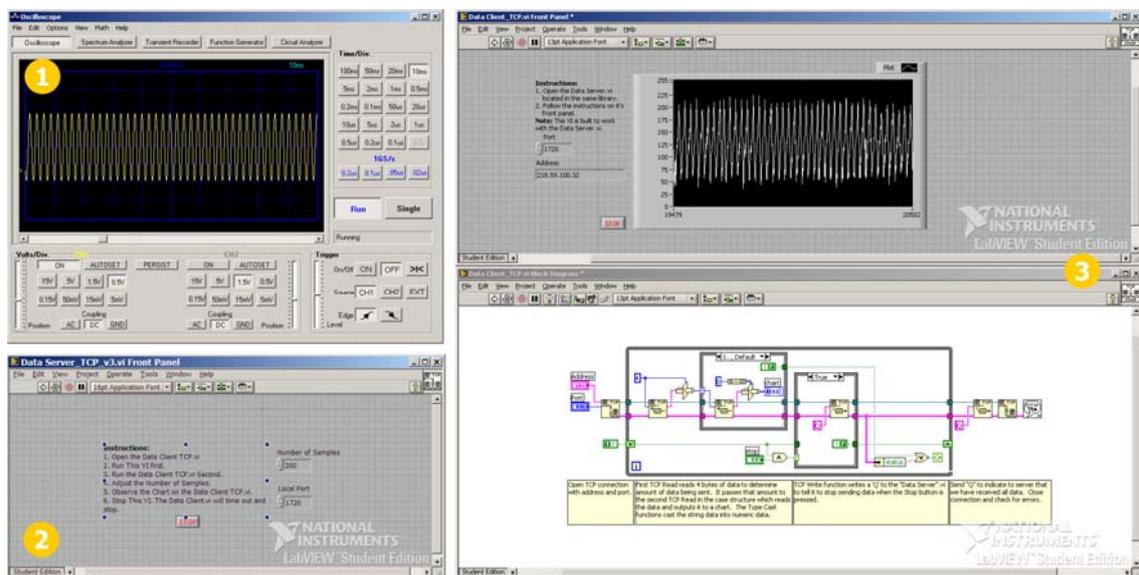


Figure 3. Wellman PCS-500 Digital Oscilloscope (1), TCP LabView Probe Front Panel (2), TCP LabView Client Front and Block Diagram (3) from different scenarios

In both cases, the buffering/delay of data on the network is observed and studied (**Roundtrip Time** for TCP and the **Jitter** for UDP).

Before each measurement the data link is investigated with a bandwidth and reliability test (loss of packets, delays) using a dedicated tool, in this case Jperf/Iperf. For bandwidth measurement Ethernet/WireShark was also used. Jperf Bandwidth and the Ethernet IOGraphs are expressed in kbps/s (Y-kbps, X-sec)

Lab View Transmission

The stimuli are sent via TCP or UDP on the already established PDP (Packet Data Protocol) between mobile and PLMN (GGSN) using the defined Lab View functions for TCP (Figure 4) and UDP (Figure 5) Transport.

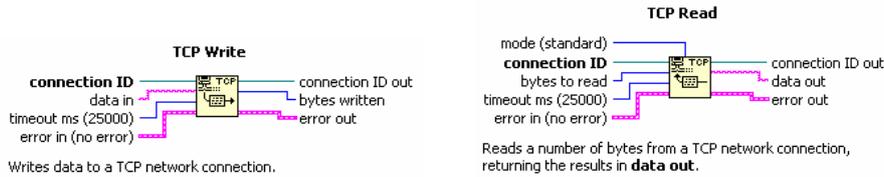


Figure 4. Lab View's TCP Write and TCP Read Elements

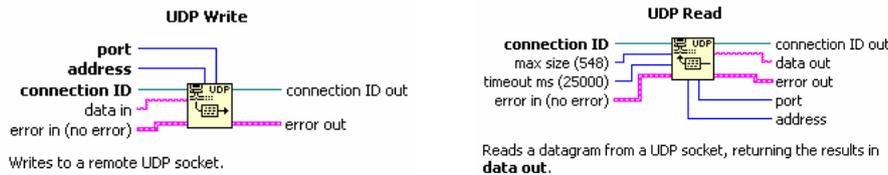


Figure 5. Lab View's UDP Write and UDP Read Elements

Using these functions four peered Vis are developed for client (DL) and probe (UL) transmission on TCP or UDP. From the Probe Lab View programs the number of points (samples) to be sent can be chosen. The maximum value is 5000. All tests are done with a value of 200 samples.

IV. Methodology

This study evolves from a previous topology in remote measurement. The studies performed at the "Transilvania" University in Brasov and at the National Technical University of Athens were centered around probe-client solution (server-workbench) involving an all Ethernet transmission medium, apart from the acquisition system, in that case a National Instrument PCI-6024E (Sandu, Balica, 2003). The current study is centered on the capabilities of the cellular network and real time transmission; the probe/client role in this case is played by the mobile equipment and the GGSN (access point from the core network to the Internet – assigning the IP for the mobile station).

The mobile equipment is connected to the network, the data packet mode activated. Simulated or real measurement is transmitted between the Lab View synchronized client and probe programs (Figure 3). After every 50 seconds the Time/Div setting on the oscilloscope is decreased from the starting rate of 100ms to lower ones as 5us. This leads to a more frequent buffer filling and to a higher rate of transmission. The higher the rate, the higher is the probability of longer RTT (TCP) or higher Jitter (UDP).

A.1. EDGE DL Access on TCP

In Figure 2 a) the first scenario is represented. The bandwidth available is measured with Jperf and Ethereal/Wire Shark both at the client and at the probe.

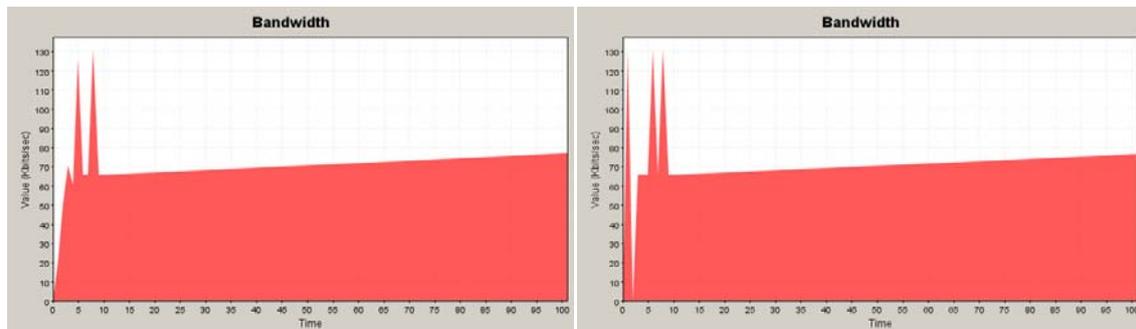


Figure 6. Jperf/Iperf measurement of the bandwidth [kbps/s] on DL TCP for the probe (left) – 70 kbps/s and at the client (right) – 70 kbps/s

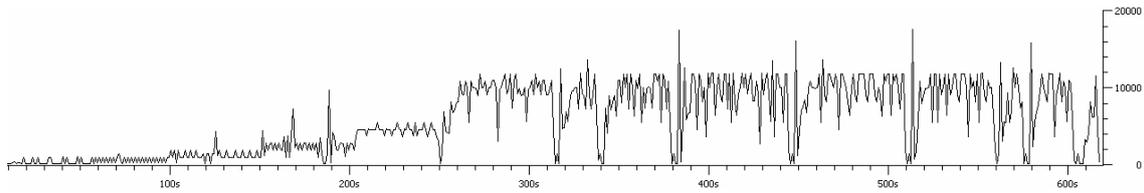


Figure 7. EDGE TCP transfer [bps/s] on probe side (sending) for Time/Div. from 100ms to 5us

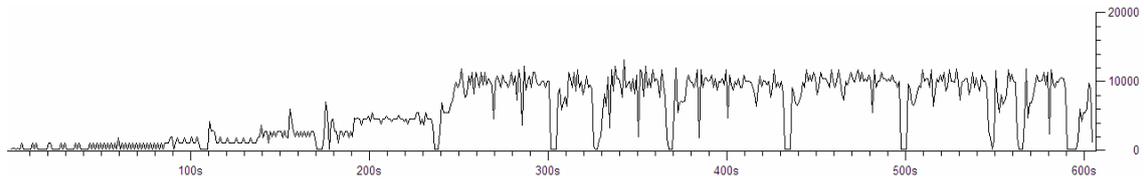


Figure 8. EDGE TCP transfer [bps/s] on client side (receiving) for Time/Div. from 100ms to 5us

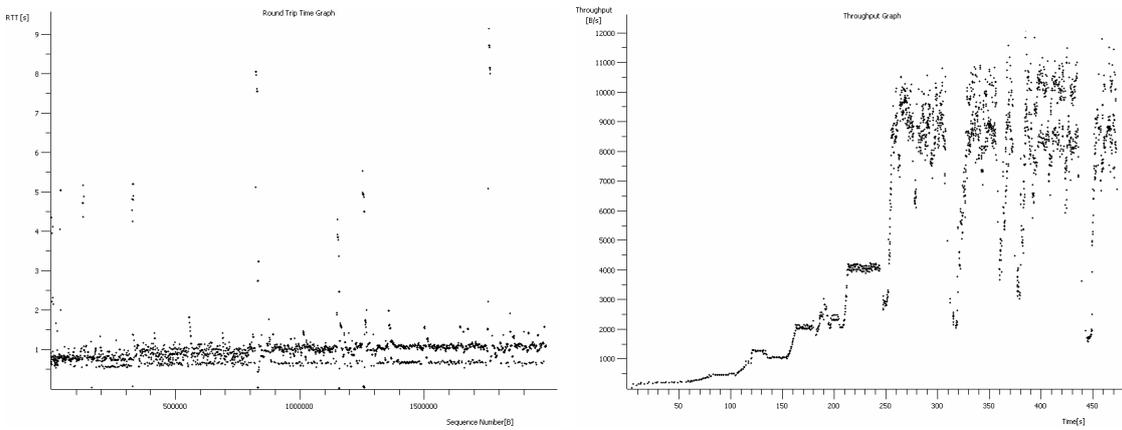


Figure 9. Round Trip Time [s] (left) and Throughput [B/s] (right) at the probe for DL TCP Transmission with congestion periods

A.2. EDGE DL Access on UDP

It is using the same scenario as in Figure 2 a).

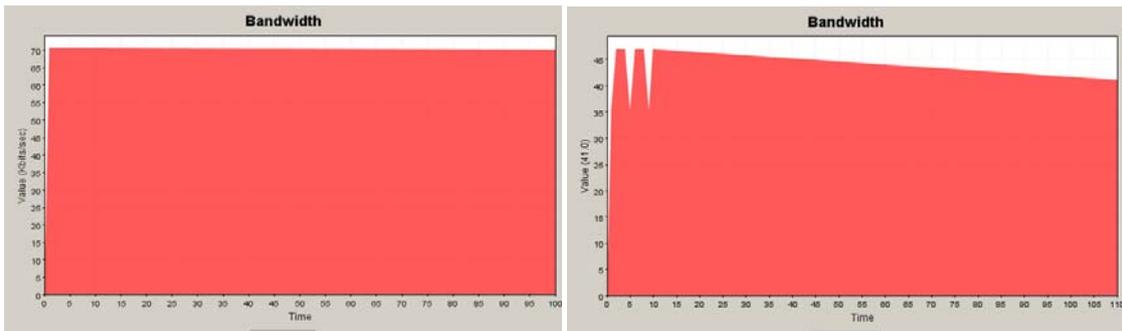


Figure 10. Jperf/Iperf measurement of the bandwidth [kbps/s] on DL UDP for the probe (left) – 70 kbps/s and at the client (right) – 45 kbps/s

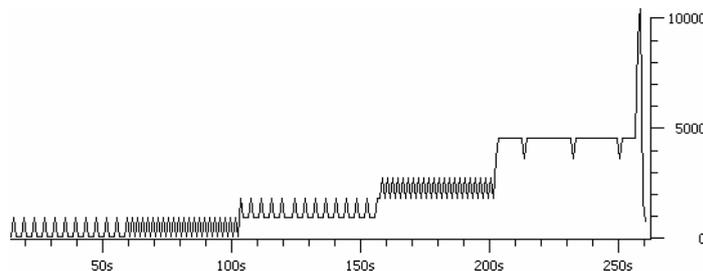


Figure 11. EDGE UDP transfer [bps/s] on probe side (sending) for Time/Div. from 100ms to 2ms

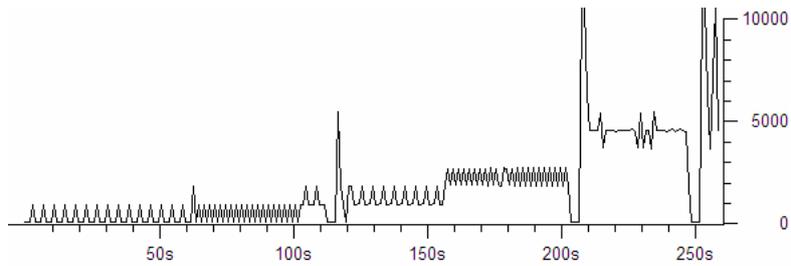


Figure 12. EDGE UDP transfer [bps/s] on client side (receiving) for Time/Div. from 100ms to 2ms

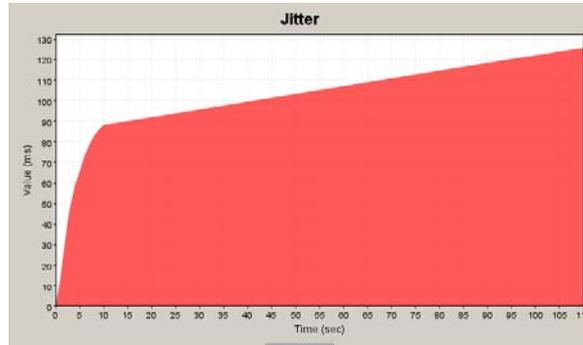


Figure 13. Jitter [ms] at the client for DL UDP Transmission - ~110 ms

B.1. EDGE UL Access on TCP

It is using the scenarios as in Figure 2 b). First the bandwidth is investigated using Jperf/Iperf and Ethereal/Wire Shark both at probe and client.

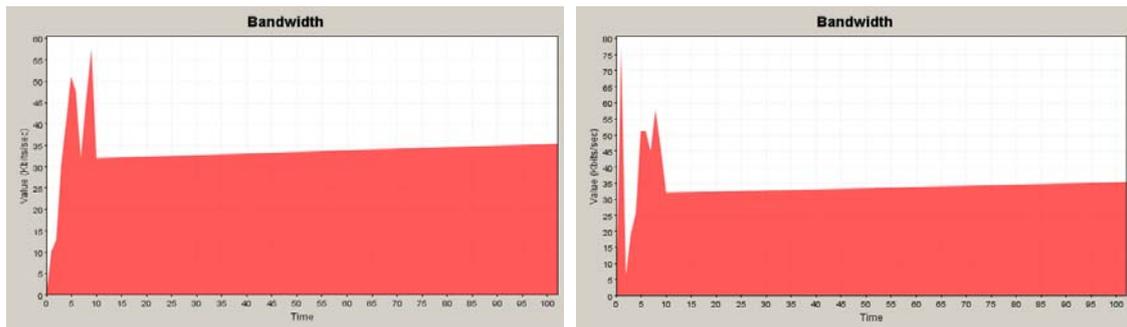


Figure 14. Jperf/Iperf measurement of the bandwidth [kbps/s] on UL TCP for the probe (left) – 32 kbps/s and at the client (right) – 32 kbps/s

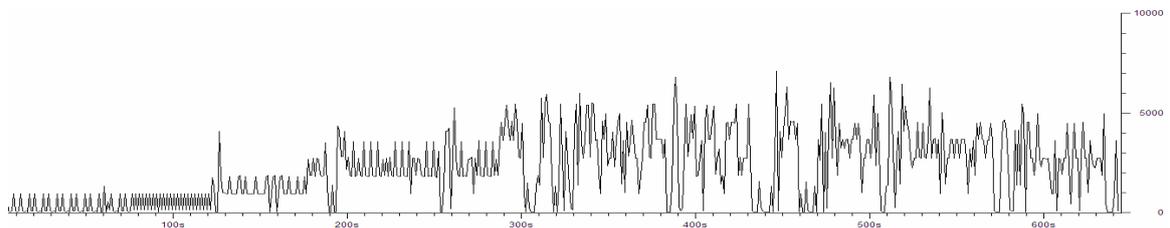


Figure 15. EDGE TCP transfer [bps/s] on probe side (sending) for Time/Div. from 100ms to 1ms

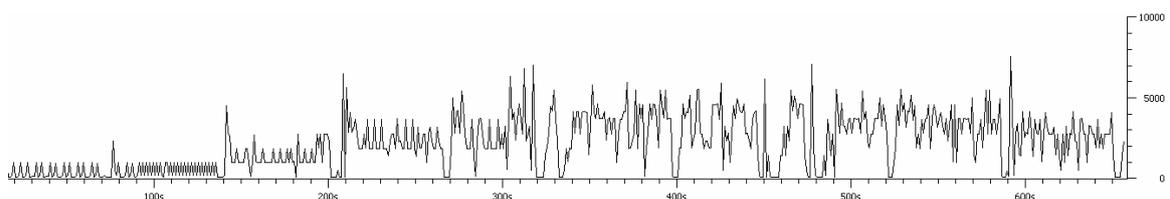


Figure 16. EDGE TCP transfer [bps/s] on client side (receiving) for Time/Div. from 100ms to 1ms

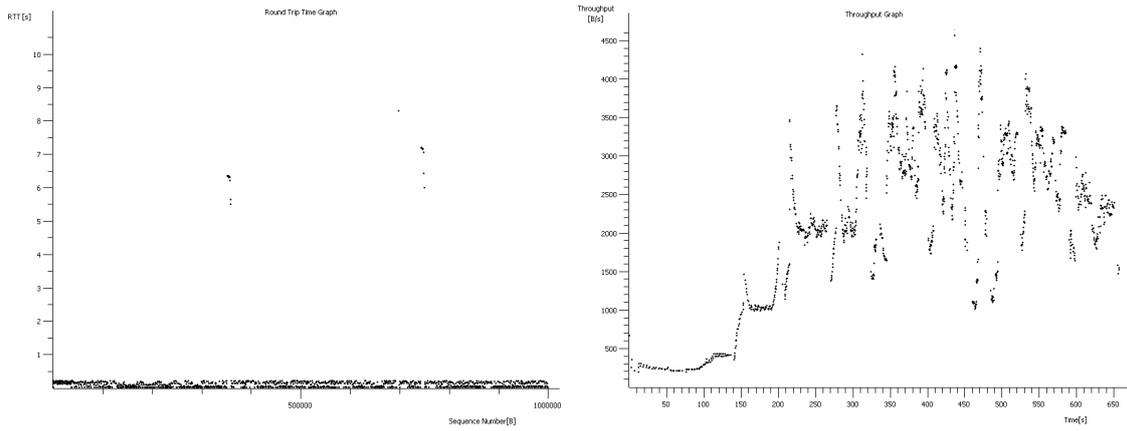


Figure 17. Round Trip Time [s] (left) and Throughput [B/s] (right) at the client for UL TCP Transmission

B.2. EDGE UL Access on UDP

It is using the scenarios as in Figure 2 b). First the bandwidth is investigated using Jperf/Iperf both at the probe and at the client.

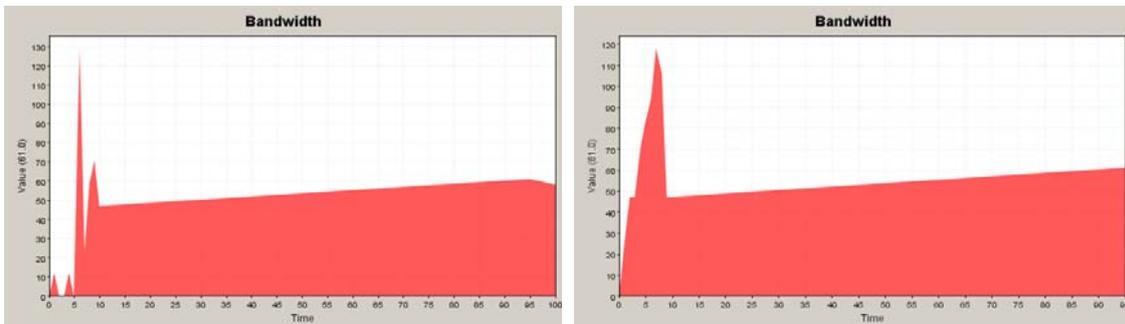


Figure 18. Jperf/Iperf measurement of the bandwidth [kbps/s] on UL UDP for the probe (left) – 61 kbps/s and at the client (right) – 61 kbps/s

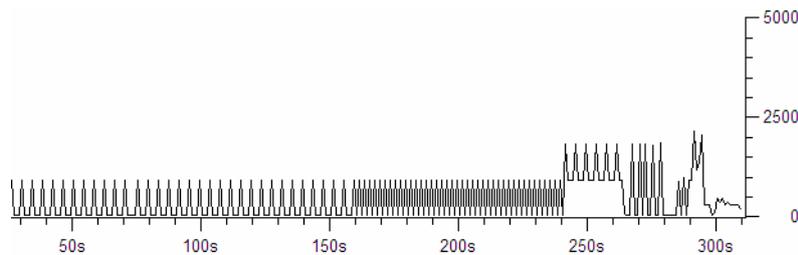


Figure 19. EDGE UDP transfer [bps/s] on probe side (sending) for Time/Div. from 100ms to 20ms

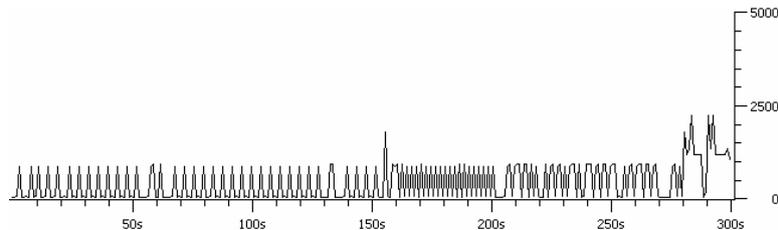


Figure 20. EDGE UDP transfer [bps/s] on client side (receiving) for Time/Div. from 100ms to 1ms

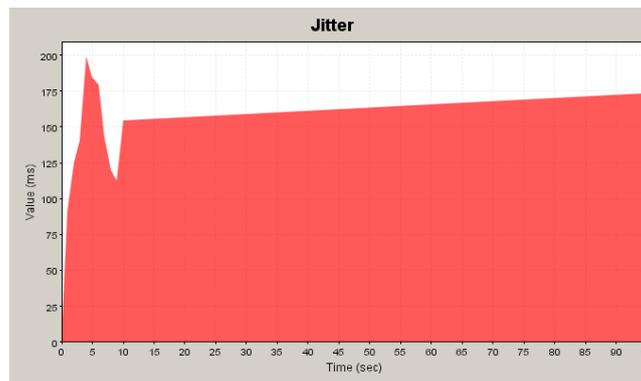


Figure 21. Jitter [ms] at the client UL UDP Transmission - ~ 160ms

IV. Conclusions

The radio transmission is studied according to the upper layers; the study is not done to the wave characteristic but to the service level provided by the radio capability. The performance of the transmission and the quality of measurements are given by the accuracy of the received data, in this case, as no modifications are done on the communication channel, the only misbehavior can come from disturbance on the transmission channel. This disturbance in a packet oriented network results in the loss of packet (Jitter, Round Trip Time). The degree of the disturbance is measured by summing the lost packets resulting in an easy to investigate proof of error (Throughput).

We can observe that for all cases, the set up period (~10 s) involves a big variation of rate due to the establishment of radio channels and buffer filling and subsequent emptying.

For TCP DL transmission the radio IF (EDGE) reaches 40-50 kbps and the Time/Div. for the Oscilloscope can go to 1us and the transmission is in real time. However, starting with 5ms (Time/Div.) the transfer reaches a threshold (Figure 7 and Figure 8) and retransmissions are needed affecting the performance. For TCP UL the radio IF supports fewer several kbps (Figure 14) and the threshold for real time transmission is reached faster (Figure 15 and Figure 16).

For UDP DL the real time transmission is blocked faster than expected and the Time/Div. can only be lowered to 2 ms otherwise the signal is updated seldom. For UDP UL the probe can transmit at lower rates and the on-line feeling is disturbed even more the Time/Div can be lowered only at 20 ms (Figure 19 and Figure 20). This is caused by the fact that in GPRS/EDGE/UMTS there are less traffic channels or radio resources allocated for UL and their priority is lower compared to the downlink channels.

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