EDGE Air Interface Testing

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Enhanced data rates for GSM evolution (EDGE) Performance Metrics

Summary

This document includes an overview on EDGE technology and recommended air interface tests using X-TEL's advanced drive test systems.

EDGE enhances throughput per timeslot for both HSCSD (ECSD- enhanced circuit switched data) and GPRS (EGPRS enhanced general packet radio service). In EGPRS the data rate per timeslot triples and the peak throughput, with all eight timeslots in use, can reach 473 kbps. This document focuses on EGPRS quality and performance metrics that can be measured and analyzed in the field.

EDGE

Enhancements that make EGPRS rates possible include the use of new modulation techniques and error-tolerant transmission methods. A PDTCH/F using GMSK modulation carries information at an instantaneous bit rate up to 22.8 kbps. A PDTCH/F using 8-PSK modulation carries information at an instantaneous bit rate up to 69.6 kbps. The 8-PSK signal is able to carry 3 bits per modulated symbol versus 1 bit per symbol using GMSK. This increased throughput comes at a cost of decreased sensitivity of the 8-PSK signal. Thus, the highest data rates have limited coverage areas since they can only be provided in areas with adequate signal strength.

EGPRS also introduces a new set of coding schemes and quality metrics used with improved link adaptation mechanisms and incremental redundancy. The next section includes a description of the Modulation and Coding Schemes (MCSs) and the quality metrics used to evaluate the radio link. The document concludes with three important performance metrics that can be used to evaluate the health of the data network – reliability, throughput and delay.

Radio Link Quality Metrics

EGPRS has an impact on the RF and physical layer of the radio interface and on the RLC/MAC protocol. Link Quality Control (LQC) for EGPRS is modified to include incremental redundancy (IR) in addition to link adaptation mode found in GPRS. The LQC includes nine different modulation and coding schemes (MSC 1-9), shown in Table 1, as well as procedures for switching between different MCSs.

Table 1 Modulation and Coding Scheme (MCS)

MCS	Modulation	Data Rate (kbps)	Family
1	GMSK	8.8	C
2	GMSK	11.2	B
3	GMSK	14.8	A
4	GMSK	17.6	C
5	8PSK	22.4	B
6	8PSK	29.6	A
7	8PSK	44.8	B
8	8PSK	54.4	A
9	8PSK	59.2	A

The GMSK coding schemes (MCS 1-4) are different from GPRS coding schemes (CS 1-4) because the EGPRS packets have different header sizes to support resegmentation –

retransmitting with another coding scheme. Resegmentation is not possible with GPRS. The initial MCS for a RLC block is selected based on radio link quality. The network controls the selection of MCSs based on link adaptation algorithms that include radio link quality measurements; Mean Bit Error Probability (BEP) and BEP Coefficient of Variance. The modulation coding scheme can be changed for each radio block (four bursts), but the actual adaptation rate is decided by the measurement interval.

As shown in Table 1, there are three families of coding schemes, A, B and C, that are related by payload sizes and that are used with resegmentation for retransmissions. Unlike GPRS, EGPRS can switch MCSs within a family to retransmit data using more robust coding schemes.

Bit Error Probability (BEP) Measurements

BEP is an enhancement to the channel quality measurements introduced in the Rel'99 specification. It was shown that BEP estimates the channel quality better than RxQual in varying channel conditions such as frequency hopping and varying mobile speed. GPRS performs interference measurements during idle bursts only twice per 240 mS period. BEP is estimated for every burst and is a reflection of the current C/I, the time dispersion of the signal and the velocity of the terminal. A mean BEP is calculated per radio block (four bursts) as well as the variation over the four bursts. This enables quick reaction to changes in the radio link, improving link adaptation.

BEP has a higher accuracy than RxQual. The measurements reported by the mobile station (MS) for the network are MEAN_BEP and CV_BEP where the MEAN_BEP (ranges from 1 to 32) is the average of the block mean BEP during the reporting period and the CV_BEP (ranges from 1 to 8) is the average of the block Coefficient of Variation (CV = Std(BEP)/Mean(BEP)) during the reporting period. Higher relative MEAN_BEP values (1-32) correspond to lower actual BEPs. Higher CV_BEPs (1-8) indicate lower actual CV and greater data consistency. Lower CV-BEPs indicate a higher actual CV and greater dispersion around the mean. Look up tables of MEAN_BEP versus CV_BEP can be used in the link adaptation process to select the appropriate MCS for the radio link environment. MCSs and hence throughput increase as the MEAN_BEP and CV_BEP values increase.

X-TEL Equipment Configuration for EDGE Testing

There are four main procedures to perform EDGE testing with X-TEL tools after the software is properly installed on the user's laptop or tablet computer. These include executing the Xi software with EDGE testing devices enabled; attaching to an EDGE network; running the X-TEL FTP or data scripting utility; and viewing real time and post processed results.

1. Run Xi software and enable EDGE testing devices – Nokia 6200 test mobile

(Reference Section 1.1.1 in Xi Users Manual)

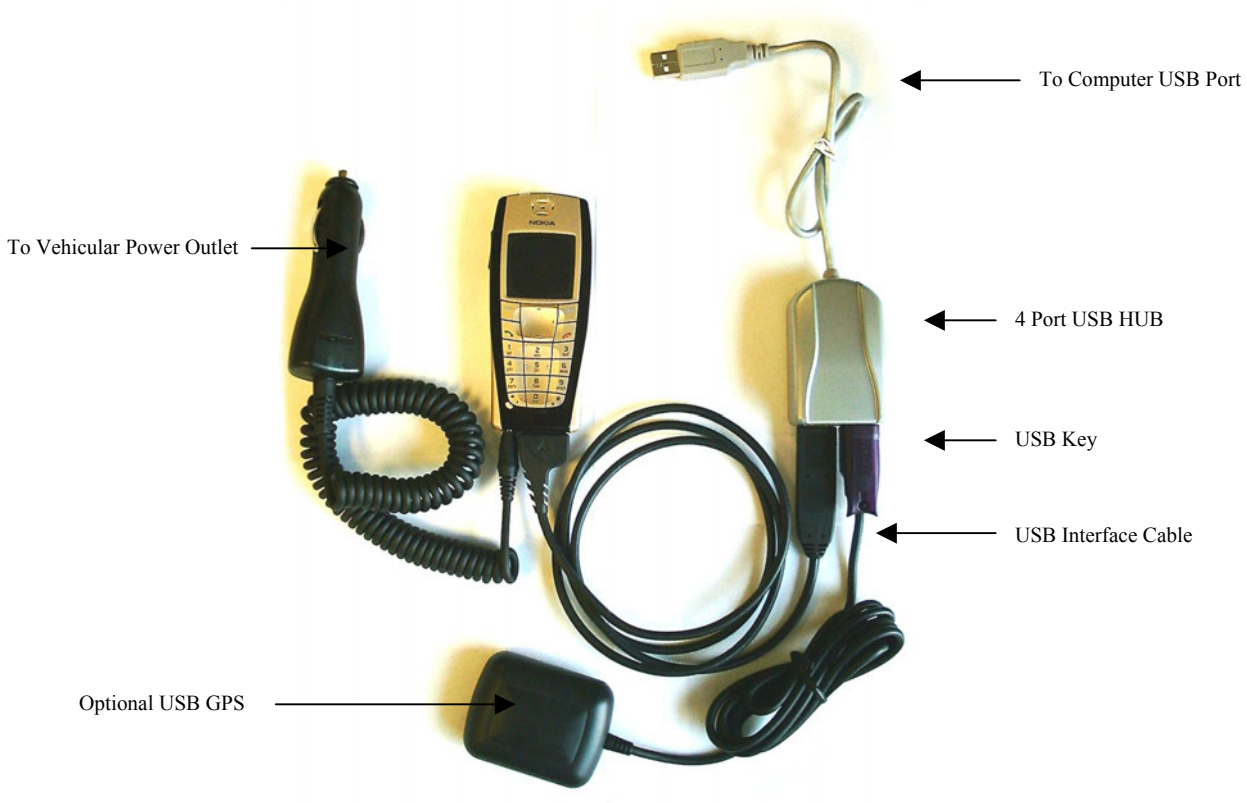
1) Configuring the phone in the Xi software
   A) Connect both the phone and the USB Key to the USB ports on the computer (see section 2.11 for more information on the USB Key). **The proper connection procedure demands that the connections be performed in the following order:**
      i. **Boot up computer**
      ii. **Connect Nokia 6200 USB Cable to computer (or to a USB HUB if it is used)**
      iii. **Connect Nokia 6200 phone to USB cable**
      iv. **Power on Nokia 6200 phone**
      v. The USB key can be plugged in at any time

*Note that once the Nokia 6200 cable is plugged into the computer, it should remain in. If it is removed for any reason, the computer will need to be restarted before the cable can be plugged in again. We are working together with Nokia to find a solution to this issue.

B) Open the Xi software and choose Options/USB Interface.
C) Select the "Enable USB Interface" option in the upper left corner.
D) In the first available slot, choose "Nokia 6200"
E) Under Serial Port, choose the Com port that has been assigned to the Port 1 on Nokia adapter device.
F) Under Shortcut key, choose a button that will be used to open screens with this phone. X-TEL recommends the "o" key. (For example, if the MAHO Status Screen is opened for a TDMA phone in slot 1, clicking on the MAHO Status Screen to make it active and then pressing the "o" key will change it to display the information for the Nokia 6200.)
G) Decide if the phone will be used to test calling with the GSM system or data services with the GPRS/EDGE system. If data is to be tested, the "Internet Dedicated" option needs to be selected, otherwise, do not select this option.

(For more information on the software configuration, see section 3.4 USB Configuration)

2) When all other devices have been configured with the HCU using the Options/PC settings, press "Go" to enable hardware and all USB and HCU devices will communicate together
   A) To connect the Nokia 6200 phone for testing with the X-TEL system, two cables are required.
   B) First, connect the USB data cable from the phone to the USB port on the computer (a USB key will be required, as will a USB HUB if only one USB port is available on the computer)
   C) Next, connect the DC charger from the phone to the power source of the vehicle. The resulting configuration should look like the picture below.
   D) Be sure that the field test screens on the phone are not enabled during data collection as this may cause communications errors.



3) GPRS Modem Connection
   A) Start with the computer powered up and with the phone powered down
   B) Turn the phone on and connect it to the computer via the USB cable
   C) Go to the Windows Start Menu and choose Control Panel>Phone and Modem Options
   D) Choose the Modem tab and click "Add"
   E) Select "Don't detect my modem, I will select it from a list" and press "Next"
   F) Select "Standard Modem Types" and choose "Standard 28800 bps Modem" and click "Next"
   G) Select the Com Port where the Nokia 6200 Phone is installed and click "Next"
   H) Choose "Finish" to complete the Wizard
   I) From the **Phone and Modem Options** screen, choose the new modem and select the "Properties" button.
   J) Choose the "Modem" tab and set the "Maximum Port Speed" setting to 115200
   K) Choose the "Advanced" tab. In the "extra Initialization Commands" field, enter **at+cgdcont=1,"ip","APN"** where **APN** will be the access point name of the system to be used.
   L) Setup a Dialup Networking connection for the phone by opening the Windows Start Menu and choosing All Programs>Accessories>Communications>Network Connections
   M) Choose "Create a New Connection" from the menu on the left side of the screen. This will launch the Wizard
   N) Click "Next" to continue
   O) Choose "Connect to the Internet" and click "Next"
   P) Choose "Set up my connection manually" and click "Next"
   Q) Choose "Connect using a dial-up modem" and click "Next"
   R) Select the "Standard 28800bps Modem" that was setup for the Nokia 6200 phone and click "Next"
   S) Enter a name for the connection in the "ISP Name" field and click "Next"
   T) Enter ***99#** in the "Phone Number" field and click "Next"
   U) Enter the "User Name" and "Password" information necessary to access the system (if needed) and click "Next"
   V) Choose "Add a shortcut to this connection to my desktop" and click "Finish"
   W) To dial the connection, double-click the icon that is added to the desktop for you new connection and press the "Dial" button (do this after selecting the "Internet Dedicated" option and enabling hardware). The phone will connect to the system and FTP can be used to test the connection. For more information on FTP, see section 3.11.

1.1 Important Nokia 6200 Notes

1) Nokia 6200 Error Correction Procedure

   A) If a Communications error appears, try using the "Reset the Phone" option twice
   B) If the Reset option in step 1 does not work, exit Xi
   C) Unplug the USB HUB that the Nokia 6200 phone is plugged into (if a USB HUB is not in use, simply unplug the Nokia USB cable from the computer)
   D) Power down the Nokia 6200 phone
   E) Shut Down the laptop (Note that this is not a Restart)
   F) Power up the laptop and wait for it to boot up
   G) Once the computer is fully booted, connect the USB HUB to the computer, with USB Key and Nokia 6200 cable already connected to the HUB (if the USB HUB is not used, simply reconnect the Nokia USB cable to the computer)
   H) Power on the Nokia 6200
   I) Initialize Xi
   J) Enable Hardware

   Note that in setting up the system, the Nokia 6200 USB cable should be plugged into the computer after the computer boots up.

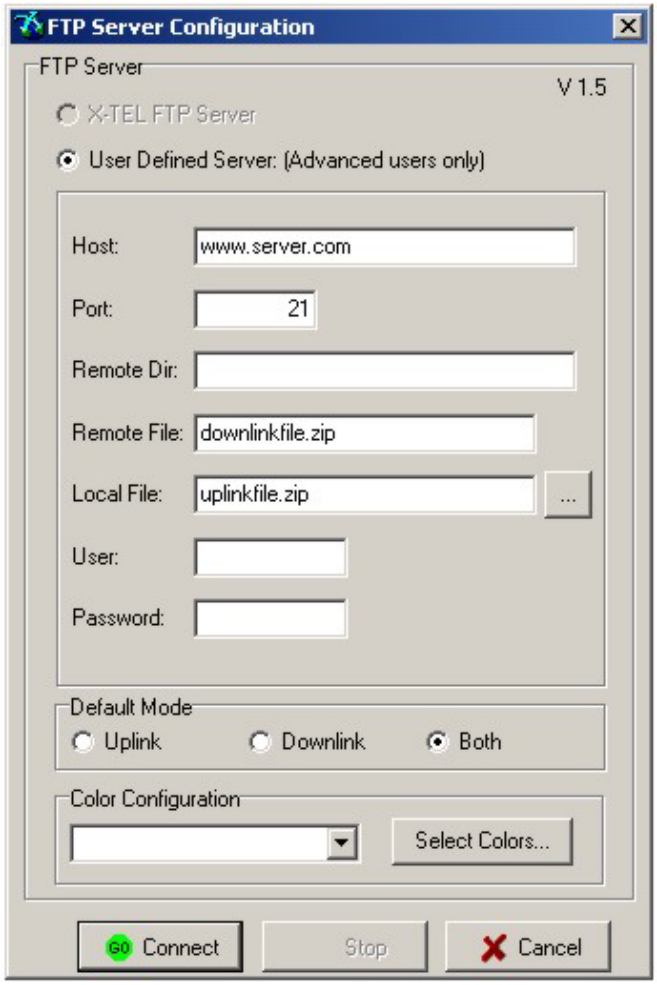
2. Attach to EDGE network

The FTP Data Speed Measurement uses the first Internet connection available on your system. Please ensure that the Internet connection that is to be tested is the only connection in the system.

It is strongly recommended that the Internet connection to be established after the hardware initialization has been performed within the Xi software. Follow the instructions outlined in section 1.4.2.2 of the manual to create a connection using the Nokia 6200.

3. Run X-TEL Automated FTP Utility; FTP Data Speed Measurement Configuration

To configure the FTP Data Speed Measurement, go to **Options\FTP Data speed measurement…**

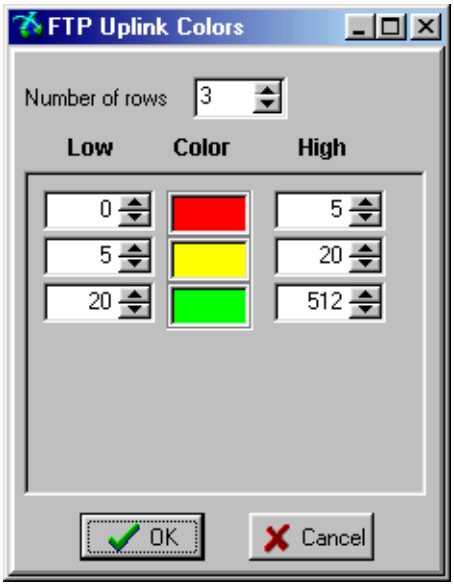


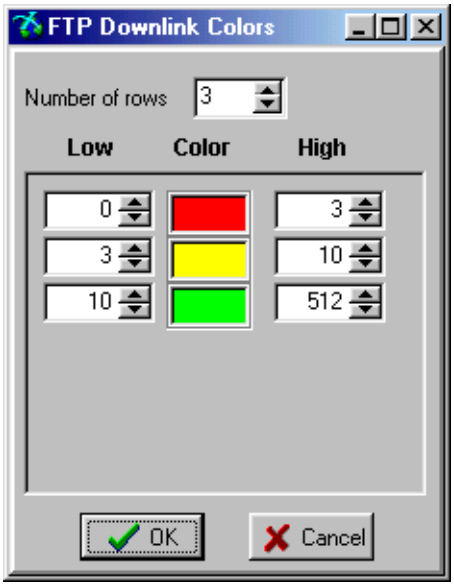
Provide the following parameters to connect to the FTP server.

- Host – the IP or Web address of the FTP server
- Port – this is the port to connect to the FTP server. This is normally 21, however, it may be something different if you are going through a firewall, or the site administrator has assigned the FTP service to a non-standard port
- Remote directory – the directory on the FTP server where the remote file is stored
- Remote file – the name of the file to be downloaded
- Local File – The name of the file to be uploaded (use the button to browse and select the desired file)

- User name – the User ID used to access the FTP server
- Password – the appropriate password for the User ID entered
- Default mode – Uplink, Downlink, or Both

Press the "Select Colors…" button to define the color ranges.





- Number of Rows – Enables the user to determine how many ranges are to be used
- Low / High – Enables the user to determine the lower and upper limits for each range
- Color – Enables the user to determine which color will be plotted to signify each range

4. Xi Real Time Displays and Rush Street Plot Analysis

The MCS information can change rapidly and it is useful to view the dynamic metrics in a rolling histogram of MCS assignments for the uplink and downlink paths.

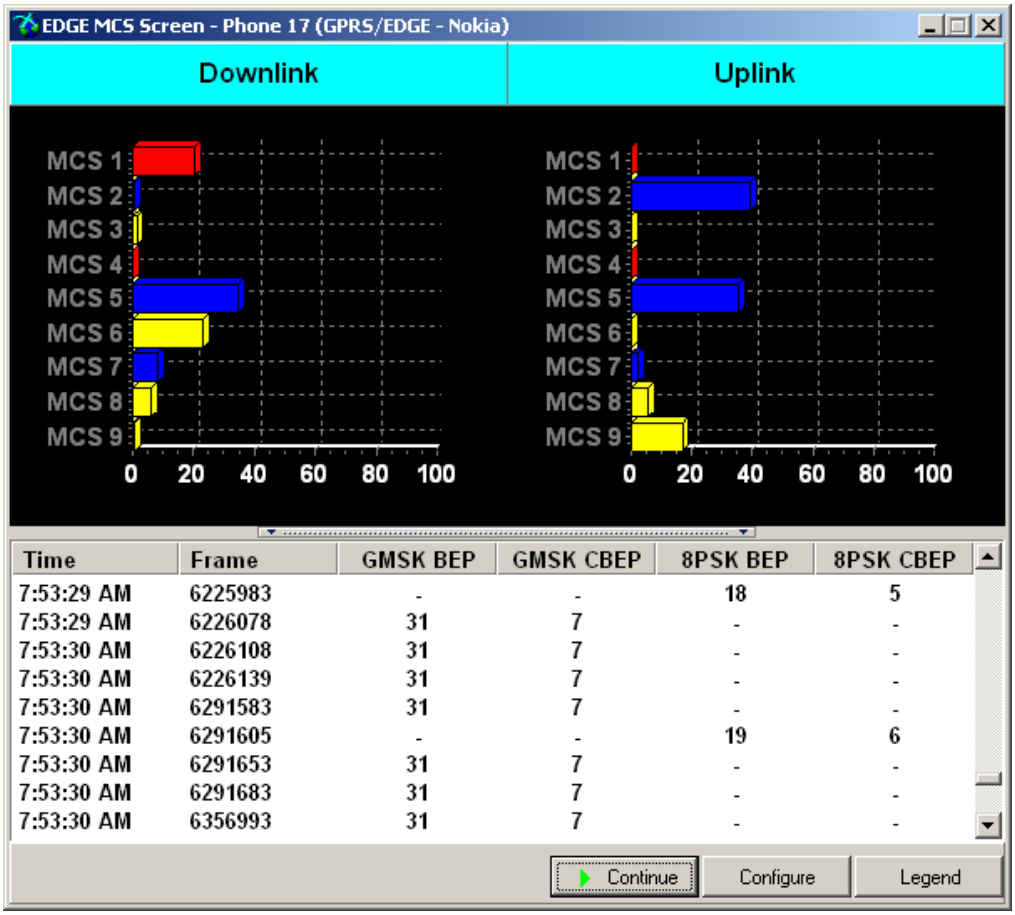


Figure 2 MCS Histogram Display

Figure 2 above shows the histogram of MCS assignments. Note that the MCS values are color coded to match their family resegmentation relationship. All raw measurements are recorded and displayed per the configuration settings. Users select the number of measurements to be displayed in the histogram and thus the time window of the measurements. This display shows the engineer the dominant MCS and link adaptation in work as MCS assignments change based on BEP mean and CV measurements.

This information can also be displayed in the EDGE SAM display, shown below in Figure 3, which includes RSSI, throughput and MCS percentage of use for the data session.

EDGE SAM Display - Phone 17 (GPRS/EDGE - Nokia)

Cell	Layer	RSSI	IP Address	MCS DL
1003		-98	10.208.168.114	6

DL Timeslots	UL Timeslots	Est. DL Thrput	Est. UL Thrput	MCS UL
2	1	6.95 Kbps	6.98 Kbps	2

	MCS-1	MCS-2	MCS-3	MCS-4	MCS-5	MCS-6	MCS-7	MCS-8	MCS-9
DL	21.0%	6.4%	2.4%	0.3%	25.7%	30.2%	5.8%	3.2%	1.3%
UL	1.7%	35.3%	2.2%	0.0%	33.6%	5.6%	3.0%	3.0%	15.5%

Figure 3: EDGE Table Display

Data Performance Metrics

Three important EGPRS radio link performance metrics in the radio access network (RAN) are reliability, throughput and delay.

Reliability

Reliability can be defined as the probability of erroneous radio link control (RLC) blocks delivered to the logical link control (LLC) layer. Reliability depends on the operation mode of the RLC layer across coding schemes. In most cases, retransmissions are required if block errors are detected. Reliability can be measured and presented as a ratio of the number of RLC data blocks correctly received for the first time across each coding scheme versus the number or retransmitted RLC data blocks across each coding scheme. Reliability measurements can be made on both uplink (UL) and downlink (DL) data transfers.

The **Serving Cell Info** window shown in Figure 4 includes LLC and RLC throughput metrics for both the uplink and downlink paths. The MCS along with the timeslot allocation will define the maximum throughput for both paths.

Shown in tabular form here, this information is also useful in line graphs and maps to show throughput rates across a coverage area.

EDGE Serving Cell Info Phone 17- (GPRS/EDGE - Nokia)

Downlink		Uplink	
RLC Throughput Kb/Sec	1.59	RLC Throughput Kb/Sec	17.09
RLC BLER	0	RLC BLER	-
RLC Num of Frames	46	RLC Num of Frames	36
RLC Num of Repeated Frames	0	RLC Num of Repeated Frames	4
LLC Throughput Kb/Sec	0.88	LLC Throughput Kb/Sec	30.04
LLC Num of Frames	269	LLC Num of Frames	270
LLC Num of Repeated Frames	0	LLC Num of Repeated Frames	0
Modulation Coding Scheme	1	Modulation Coding Scheme	9
Timeslots	2	Timeslots	1

Attached	IP Address	L1 Mode	Vocoder	Sync Status	C31
Yes	10.216.134.241	-	-	-	0

C32	Cipher Mode	Attach Status	Ready Timer	ECSC	
0	1	Combined	44	-	

Figure 4 Serving Cell Info

Throughput

Throughput is the amount of data delivered per unit of time. It is useful to view the instantaneous throughput, calculated average and percentile throughput values across the network:

A. LLC Throughput: number of bytes in the Information Field of each LLC frame, excluding header and Frame Check Sequence (FCS) received or transmitted during the observation period.
B. RLC/MAC Throughput: number of first transmissions of RLC Data Blocks of each coding scheme
C. RLC/MAC Overhead Throughput: number of RLC Data Blocks retransmitted and the RLC/MAC Control Blocks (CS-1 coded) received for that same Temporary Block Flow (TBF).

Xi's downlink and uplink EGPRS data transfer screens display GPRS specific parameters in graphical format. The graphs depict the uplink and downlink RLC/LLC throughputs, RLC/LLC retransmissions, block error rate, allocated bandwidth and actual bandwidth used.

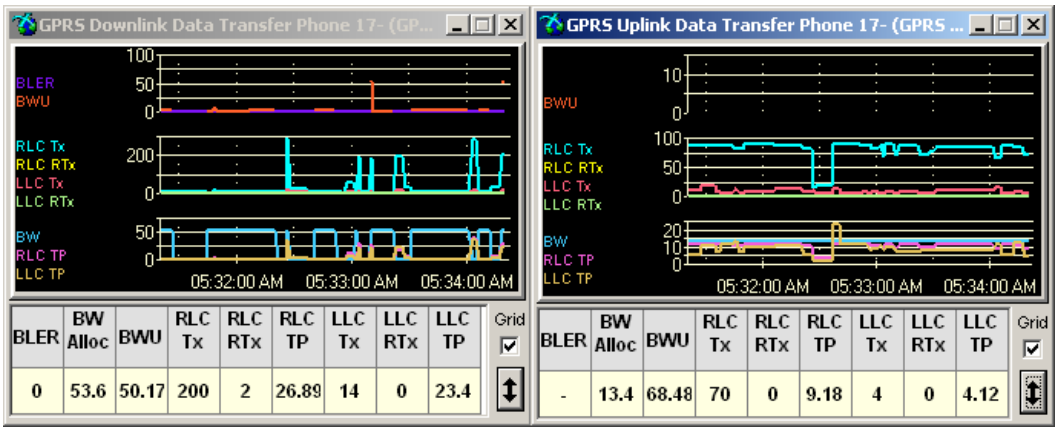
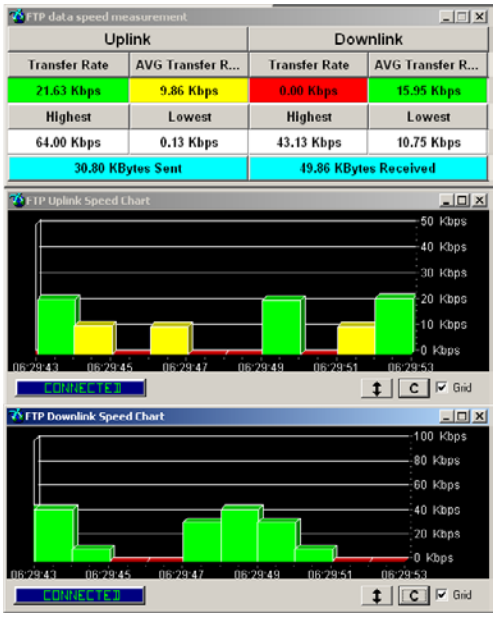


Figure 5: LLC/LLC Throughput Graphs

D. Application Throughput: number of bytes in the data field of each IP packet excluding the IP header received or transmitted during the observation period.

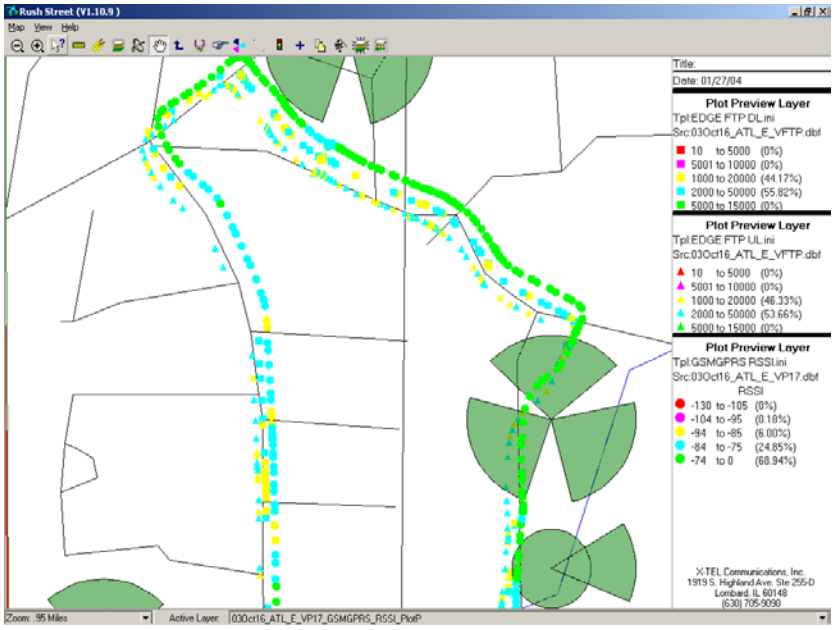
a. For downlink – time duration shall be from the time of reception of the Packet Paging to the time of the last RLC Data Block acknowledgement by the network
b. For uplink – time duration shall be from the time of the transmission of the first Packet Channel Request to the time of reception of the last IP Ack at the application layer.

Xi's automated FTP session generator displays application uplink and downlink actual and average throughput charts and tables.

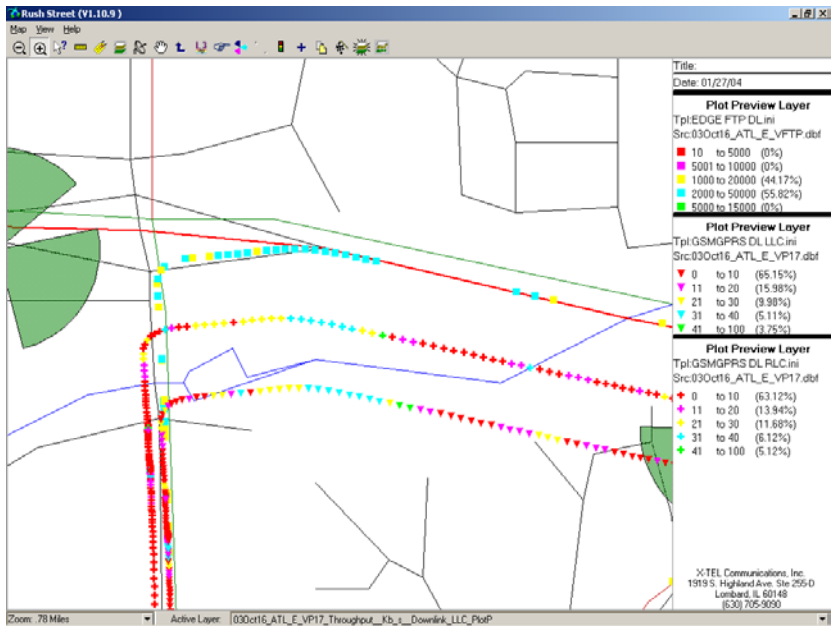


Plot Preview Analysis

X-TEL's Plot Preview Analysis can be used to view multiple layers of data. Example plots follow that show UL and DL FTP throughput plotted against RSSI, and DL FTP, DL RLC and DL LLC throughput plotted side by side. Please refer to the Xi Manual section 9.5 Plot Previews for step by step instructions.



Application Level DL and UL Throughput plotted with RSSI DL.



Downlink application throughput, downlink RLC throughput and downlink LLC throughput

Delay

Delay is defined as the time it takes for a LLC Protocol Data Unit (PDU) to be transferred from the Serving GPRS Support Node (SGSN) to the MS or from the MS to the SGSN. PING commands can be used to measure the response time at the application layer. A heavily loaded network may have excessively long response times that may disrupt application and transport layer protocols. X-TEL will soon release a ping testing application to be included with the data scripting utility.