Session 1540
GPRS/3G Wireless Networks I

Enhanced General Packet Radio Service OPNET Model

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Road map

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- Base Station Subsystem
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- Cell update
- OPNET model implementation
- Simulation scenarios and results
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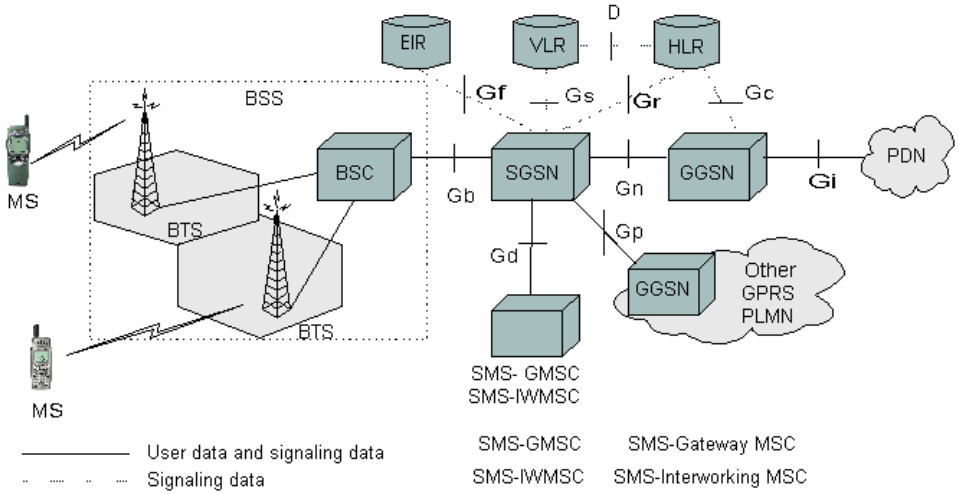
Introduction

- General Packet Radio Service (GPRS) is a packet-switched wireless network technology based on Global System for Mobile Communications (GSM).
- GSM and GPRS are standardized by the European Telecommunications Standards Institute (ETSI).
- GSM employs circuit switching technology with a data transmission rate of 9.6 kbps.
- GSM frequencies used in Europe:
  - 900 MHz and 1800 MHz
  - 1900 MHz in North America.
- GPRS offers data transmission rates up to 171.2 kbps.

GPRS overview



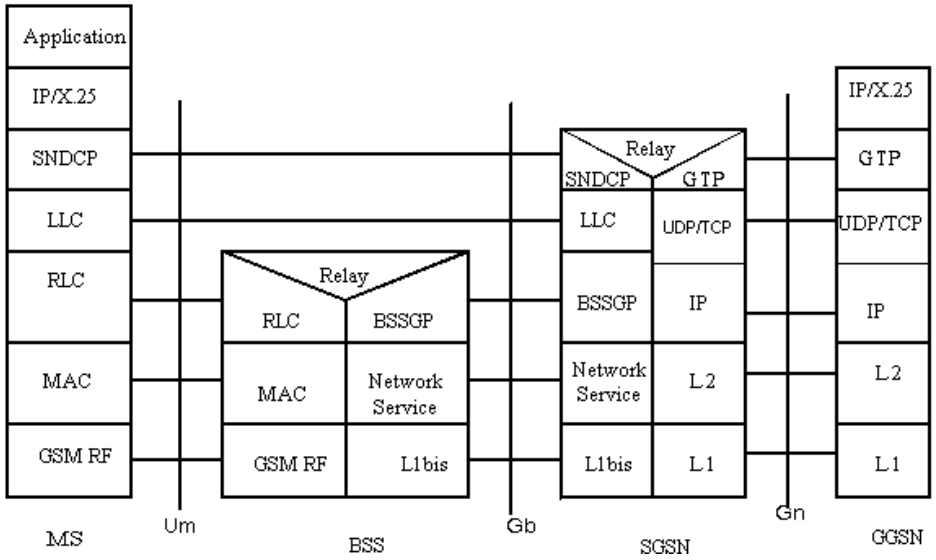
Main Components of a GPRS network:

- Mobile Station (MS)
- Base Station Subsystem (BSS)
- Serving GPRS Support Node (SGSN)
- Gateway GPRS Support Node (GGSN)
- Packet Data Network (PDN)
- Registers
  - Home Location (HLR)
  - Visitors Location (VLR)
  - Equipment Identity (EIR)

Base Station Subsystem

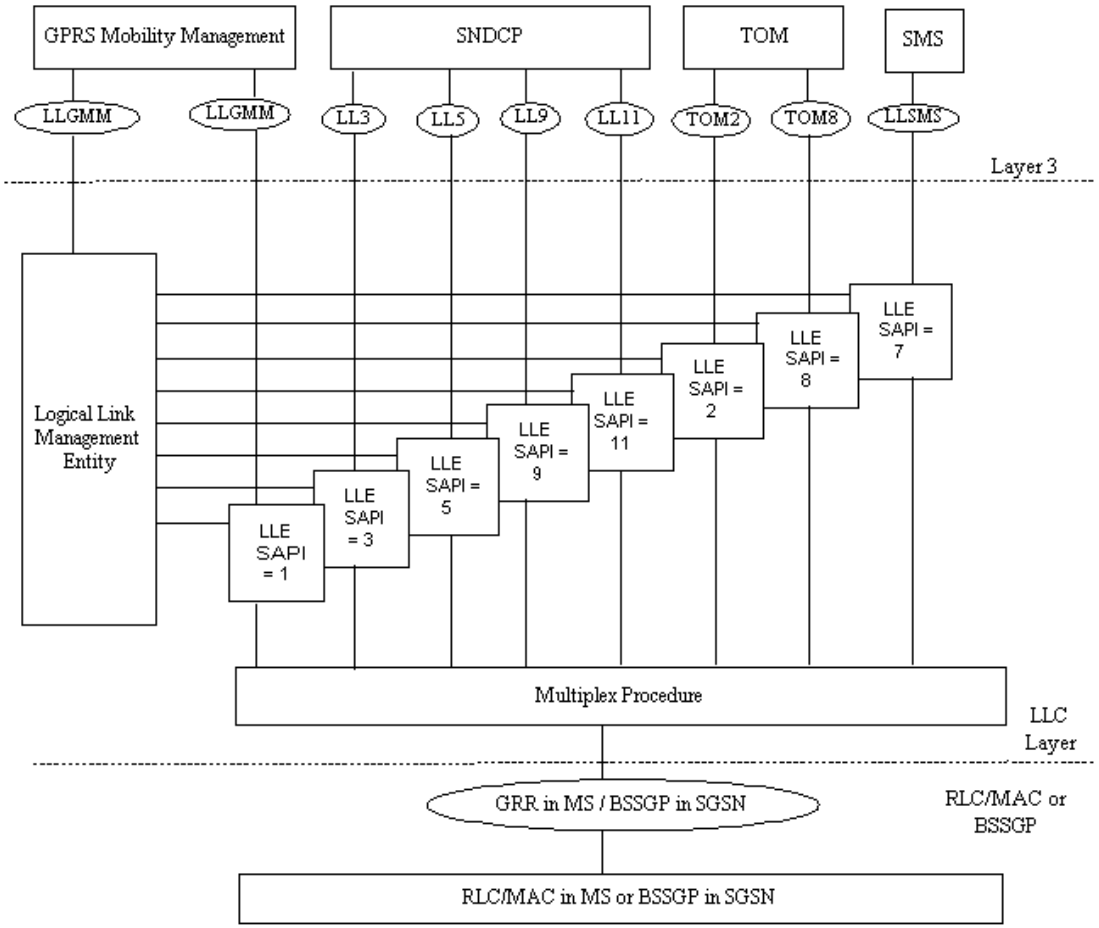
- Base Station Subsystem (BSS) consists of Base Transceiver Stations (BTSs) or Base Stations (BSs) and a Base Station Controller (BSC).
- The BSC manages the Radio Resource (RR) functions:
  - evaluating measurement results from MSs and BTSs
  - controlling handover and power for GSM connections.
- The BTS enables wireless connections of MSs to the network over the air interface.

Logical Link Control layer



- LLC, a sub-layer of layer 2 in the ISO 7-layer reference model, conveys information between layer-3 entities in the MS and the SGSN.
- Two modes of operation supported by LLC:
  - Unacknowledged peer-to-peer operation, known as Asynchronous Disconnected Mode (ADM)
  - Acknowledged peer-to-peer operation, called Asynchronous Balanced Mode (ABM).

Internal LLC layer structure



- SNDCP: Sub Network Dependant Convergence Protocol
- TOM: Tunneling Of Messages
- SMS: Short Message Service
- GRR: GPRS Radio Resource
- BSSGP: Base Station Subsystem GPRS protocol
- RLC/MAC: Radio Link Control/Medium Access Control

LLC components and functions

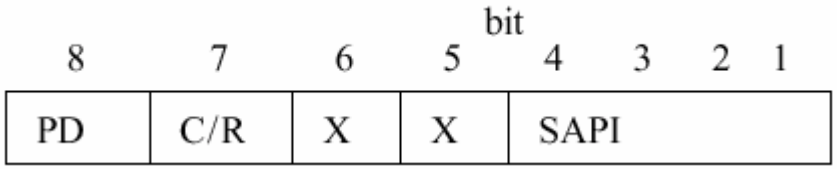
- Logical Link Management Entity (LLME) performs parameter initialization, error processing, and connection flow control invocation.
- Logical Link Entities (LLEs) control the information flow of individual connections.
- Multiplex Procedure:
  - when a frame is transmitted, it generates and inserts a Frame Check Sequence (FCS), performs frame ciphering, and provides contention resolution between LLEs.
  - on frame reception, the multiplex procedure performs the frame decipher function and sends it to the appropriate LLE after checking the FCS.

LLC frame format

- Each LLC frame consists of:
  - header (address and control fields)
  - information field
  - trailer (FCS).

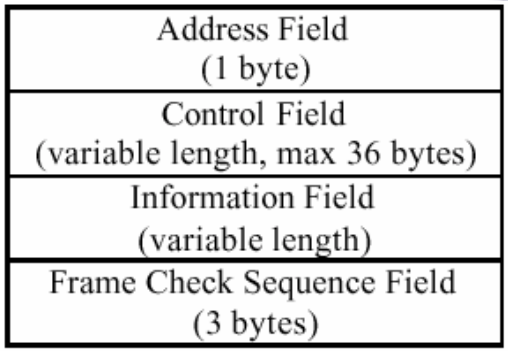
Address Field (1 byte)
Control Field (variable length, max 36 bytes)
Information Field (variable length)
Frame Check Sequence Field (3 bytes)

- Address field:
  - Protocol Discriminator (PD) bit indicates whether a frame is an LLC frame or not
  - Command/Response (C/R) bit identifies a frame as either a command or a response
  - Service Access Point Identifier (SAPI) identifies a point at which an LLE service is provided by an LLE to a layer-3 entity.



LLC frame format

- Control field identifies the frame type.
- Four types of control field formats:
  - confirmed information transfer (I format)
  - supervisory functions (S format)
  - unconfirmed information transfer (UI format)
  - control functions (U format).

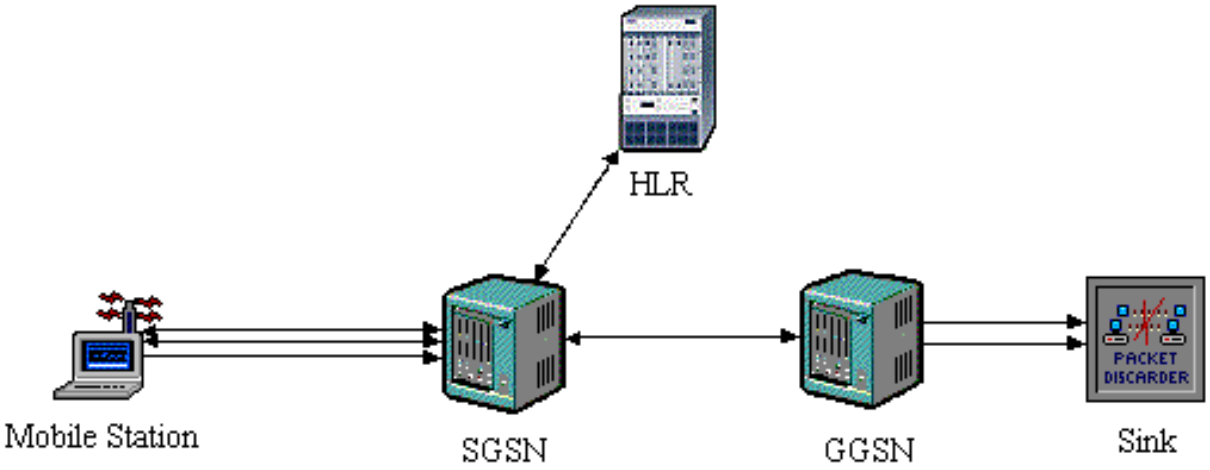


- Information field consists of 140 to 1,520 bytes depending on the format specified in the control field.
- Frame Check Sequence field consists of a 24-bit cyclic redundancy check (CRC) code. The code is used to detect bit errors in the frame header and information fields.

Cell update procedure

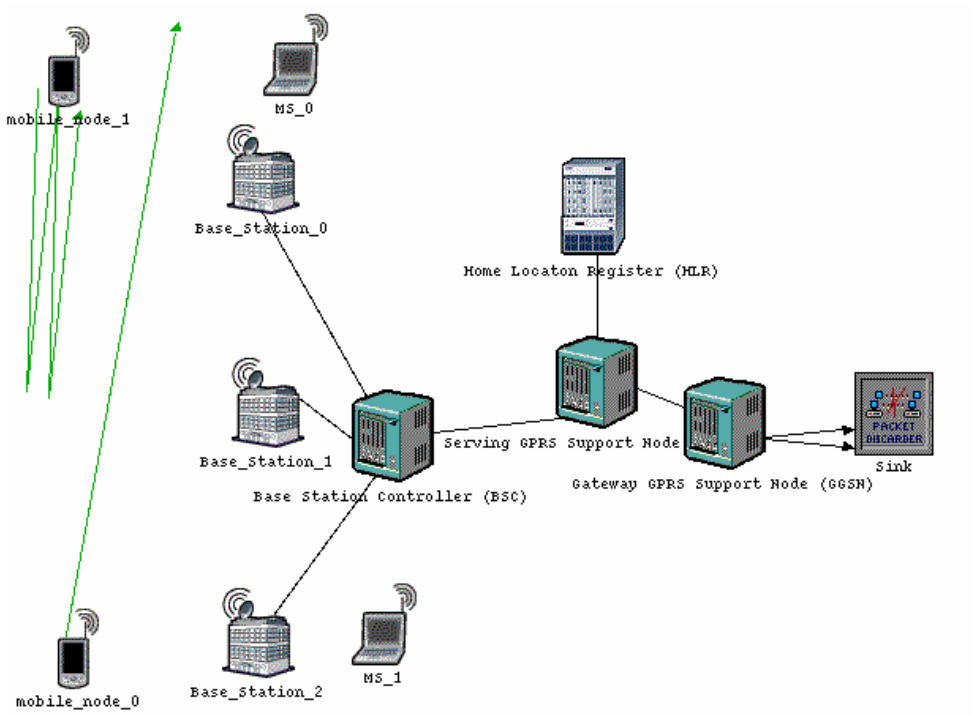
- The cell update procedure has to be performed when the MS moves to the coverage area of another BTS with better reception.
- The MS periodically measures the signal levels on the Broadcast Control Channels (BCCHs) of the serving BTS and the neighboring BTSs.
- The cell update can be controlled by either the MS or the network.
- Three modes of cell update are defined:
  - NC0: MS performs autonomous cell reselection, but does not send measurement reports to the network
  - NC1: MS performs autonomous cell reselection and periodically sends measurement reports to the network
  - NC2: Network controls cell reselection procedure.

OPNET model implementation: original model



- The original GPRS model consisted of:
  - Mobile Station (MS)
  - Serving GPRS Support Node (SGSN)
  - Home Location Register (HLR)
  - Gateway GPRS Support Node (GGSN)
  - Sink representing an external packet data network.

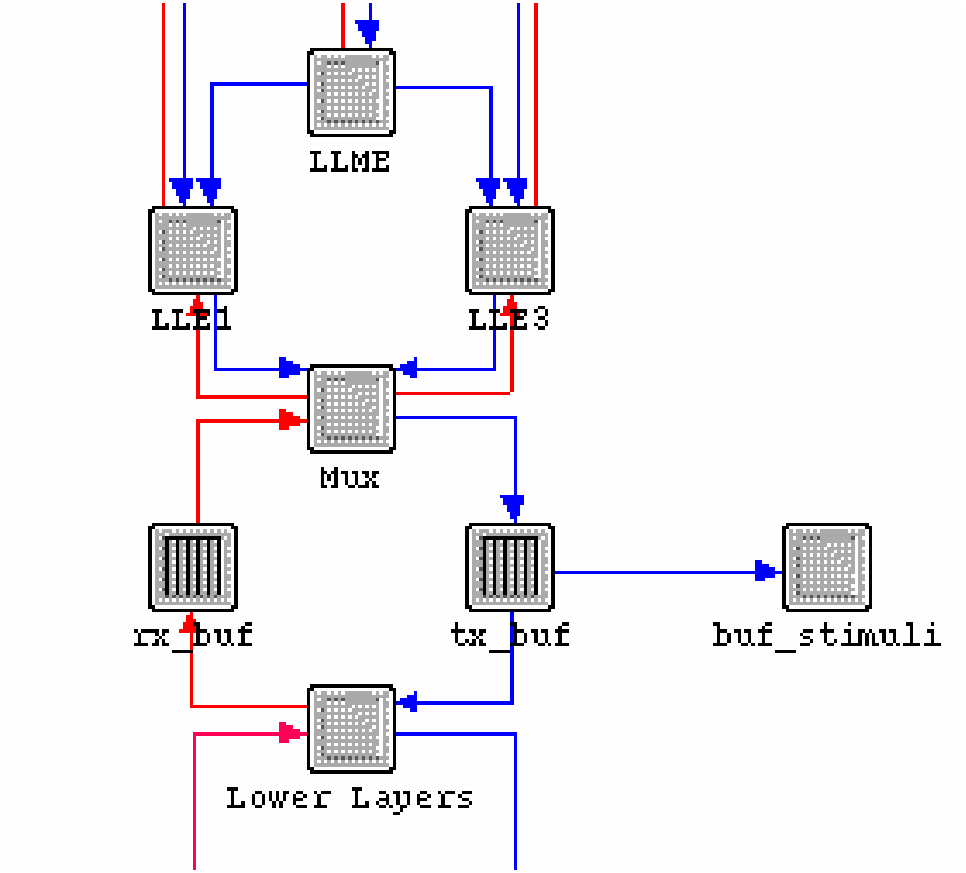
OPNET model implementation: enhanced model



- Additions and changes to the original GPRS model (OPNETWORK 2003):
  - wireless connections instead of wired links
  - multiple mobile nodes with trajectories
  - implementation of the Base Station Subsystem
  - implementation of LLC layer.

Implementation of LLC

- Additions to the node model of the MS and SGSN:



- LLME: Logical Link Manager Entity
- LLE1: ADM operation for Logical Link Entity 1 (used for GMM)
- LLE3: ADM operation for Logical Link Entity 3 (used for SNDCP)
- MUX: (De-)multiplexes messages from LLE1, LLE3, and Lower Layers, dummy implementation of RLC.

Implementation of LLC

- LLC packet format used in our implementation contains a new field, Temporary Logical Link Identifier (TLLI), not specified in the LLC specification.
- This field was added to enable functionality in an incomplete protocol stack.

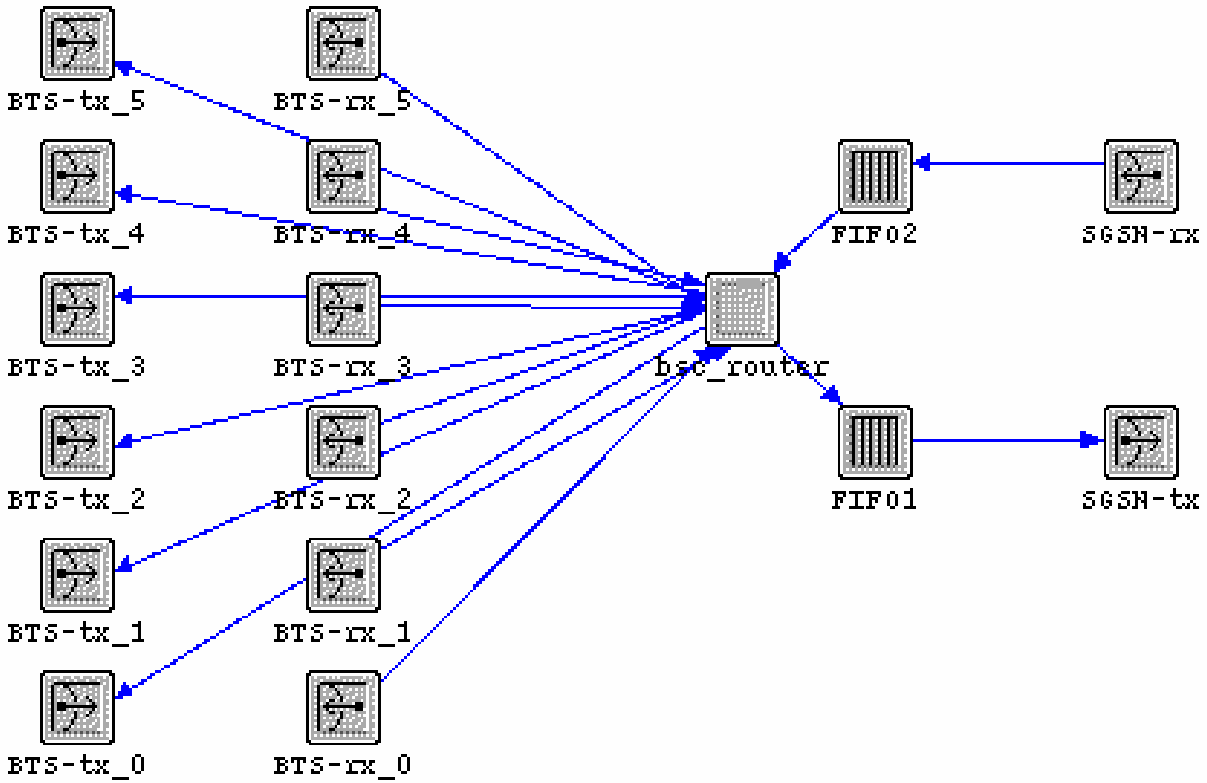
TLLI
Address (1 byte)
Control (4 bytes)
Information (variable size)
FCS (3 bytes)

Simplifications:

- We only implemented:
  - unacknowledged Asynchronous Disconnected Mode (ADM)
  - two Logical Link Entities, LLE1 and LLE3
- LLC in the SGSN and MS are identical.
- LLC does not implement the correct service primitives for communication between LLC and lower layers because BSSGP and MAC are not implemented in this OPNET model.
- Frame ciphering and error control are not implemented.

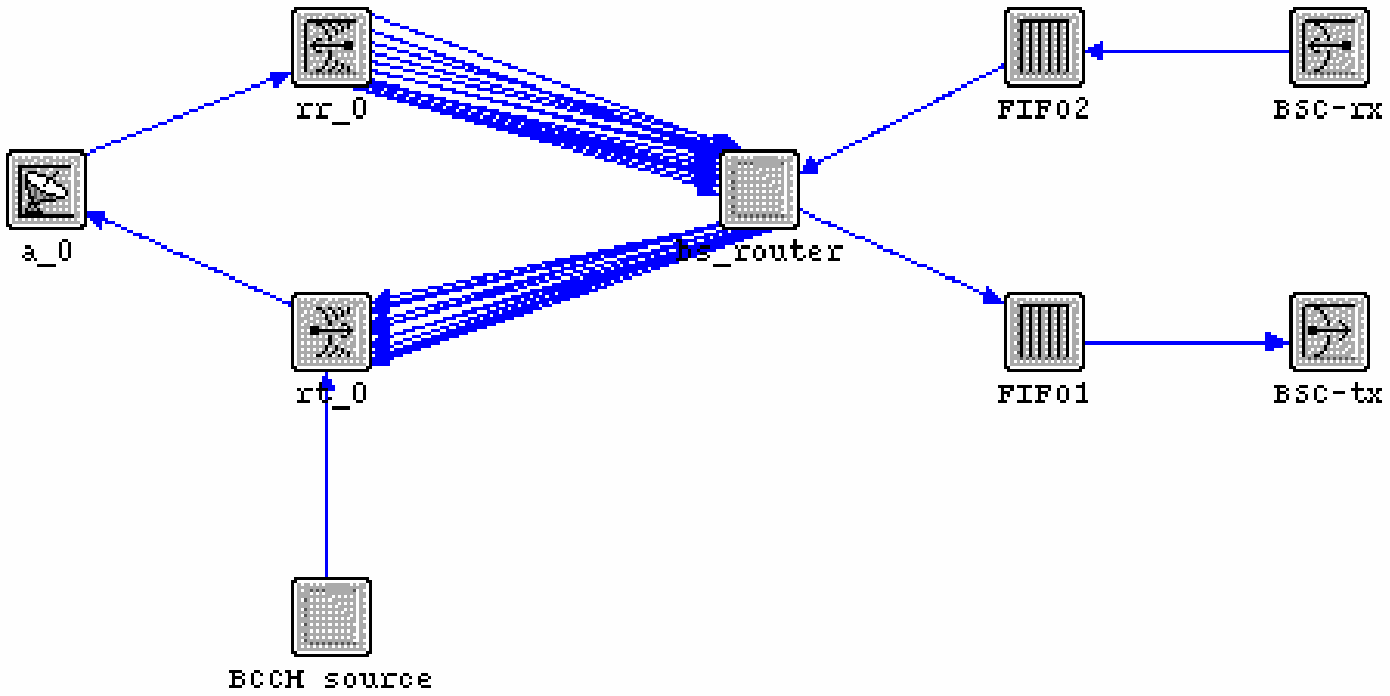
Base Station Controller

- Routes packets from the BTSs to the SGSN and from the SGSN to the BTSs based on the stream number of the incoming packet and the TLLI, respectively.



Base Transceiver Station

- Routes packets from the MSs to the BSC and from the BSC to the MSs based on the channel/stream number of the incoming packet and the TLLI, respectively.

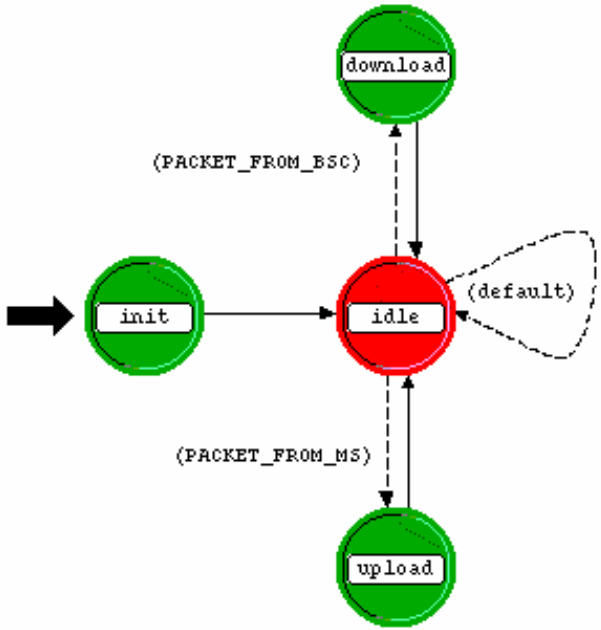


Base Transceiver Station

- BTS in this model can support 15 MSs.
- BTS has a radio transmitter-receiver pair with 15 channels.
- MSs cannot share the same frequency/channel, as the RLC/MAC layer is not implemented.
- 16th channel was added to the wireless transmitter to represent the Broadcast Control Channel (BCCH).
- Every 5 seconds, the BTS transmits a packet through the BCCH to allow power measurements in the MSs.

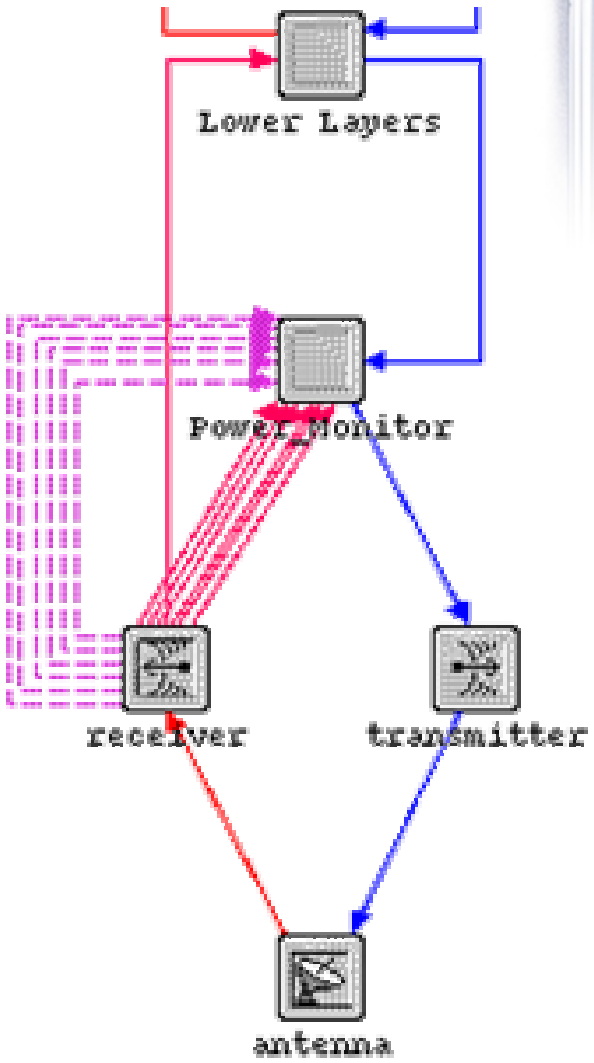
Base Transceiver Station process model

- init: computes and sets the frequency attributes of the transmitter and receiver channels
- upload: forwards packets to the BSC
- download: routes packets to the MSs



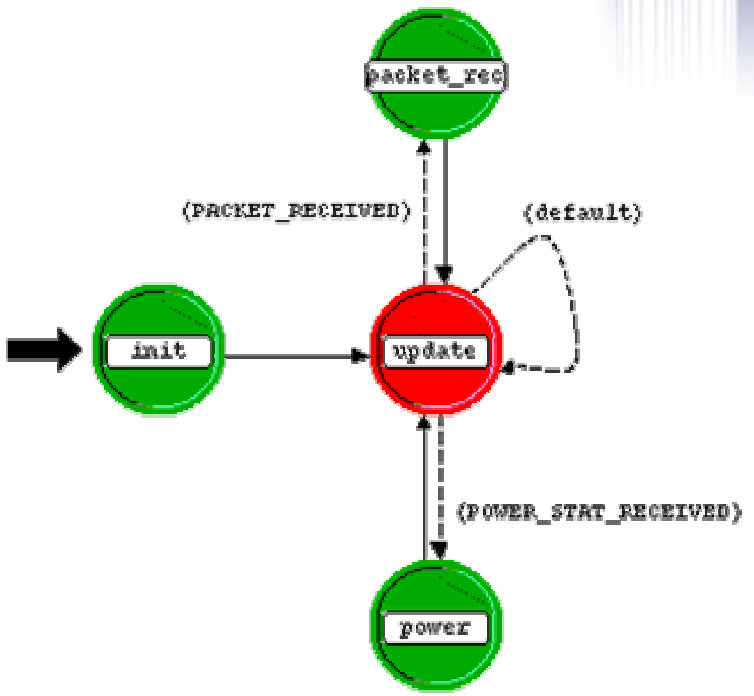
Cell update

- The MS performs autonomous cell reselection (NC0) based on the power level measurements of the 6 adjacent BTSs.
- Power_Monitor was added to the MS node model to measure the power level of the incoming signals and to transfer packets to and from the lower layers.
- The power levels from the incoming packets are obtained using the six statistical wires connected from the receiver to the Power_Monitor.



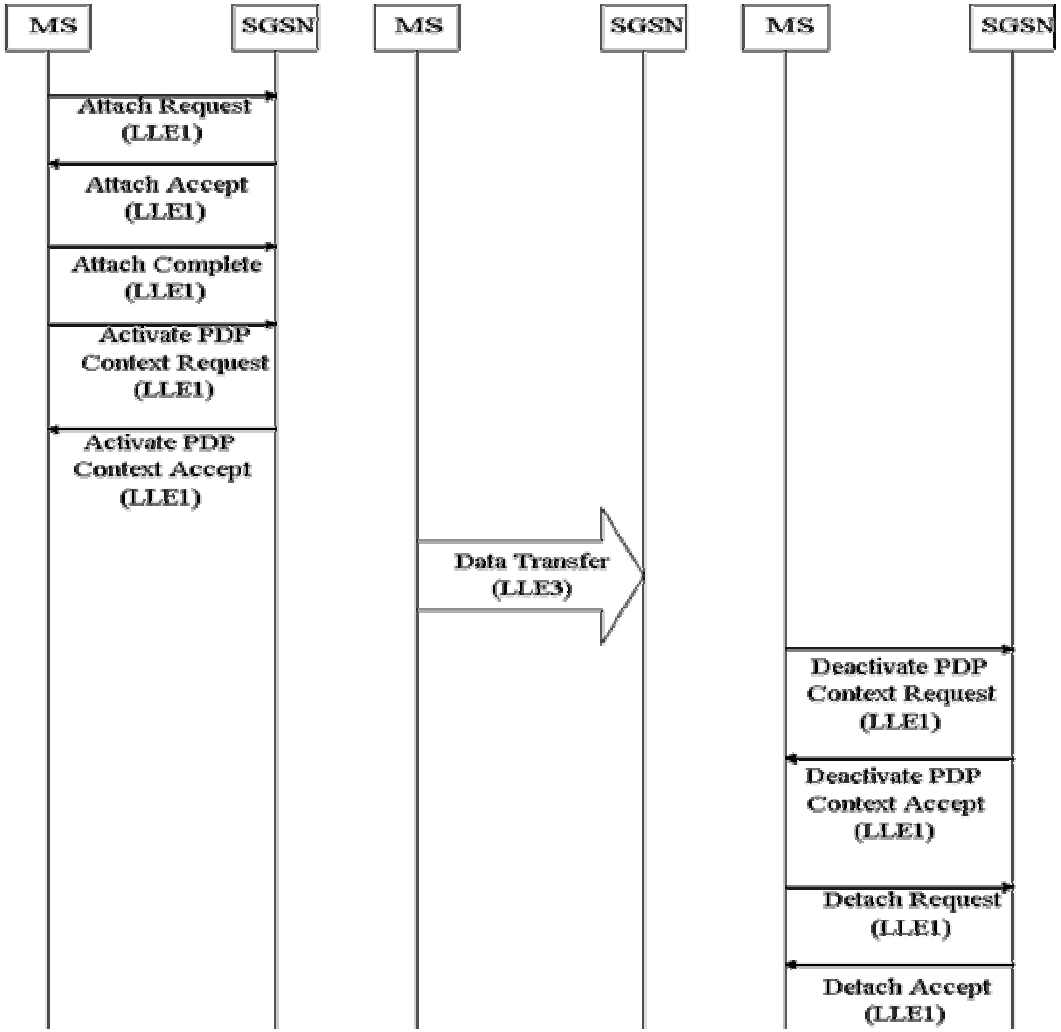
Cell update: Power_Monitor process model

- init: initializes the power table to -1
- power: stores the received power statistics in the table according to their channel/stream number
- update: identifies the channel with the highest power. It sets the transmitter and receiver frequencies and performs the cell update by sending an empty LLC frame (Flush LLC) to the SGSN
- packet_rec: forwards the packets received from the Lower Layers to the transmitter

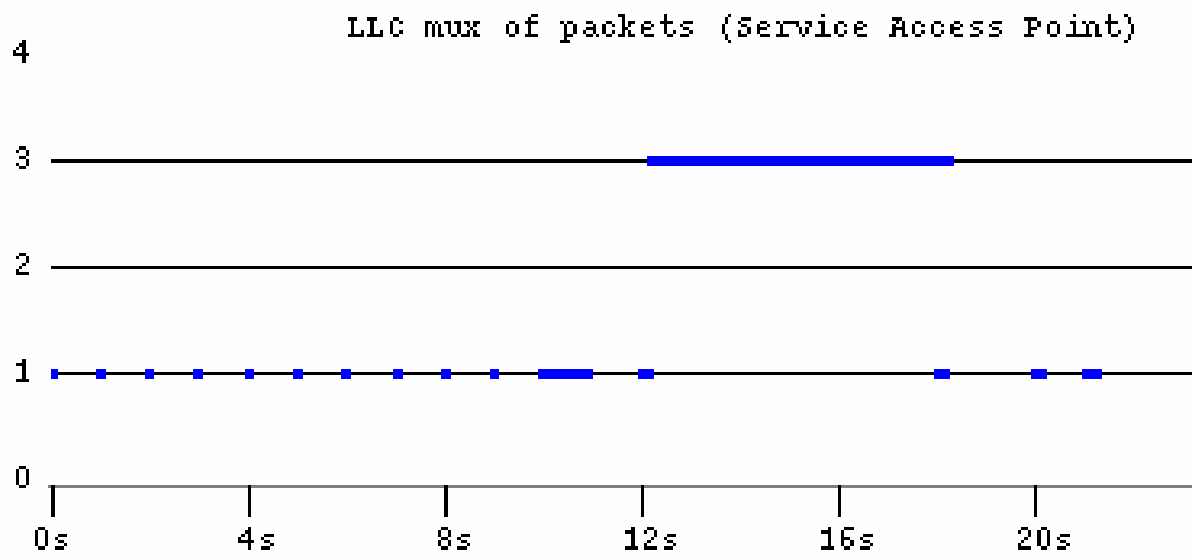


Verification of LLC implementation

- A simulation scenario is configured to set up a data connection, transfer data, and then disconnect the data connection.



Verification of LLC implementation

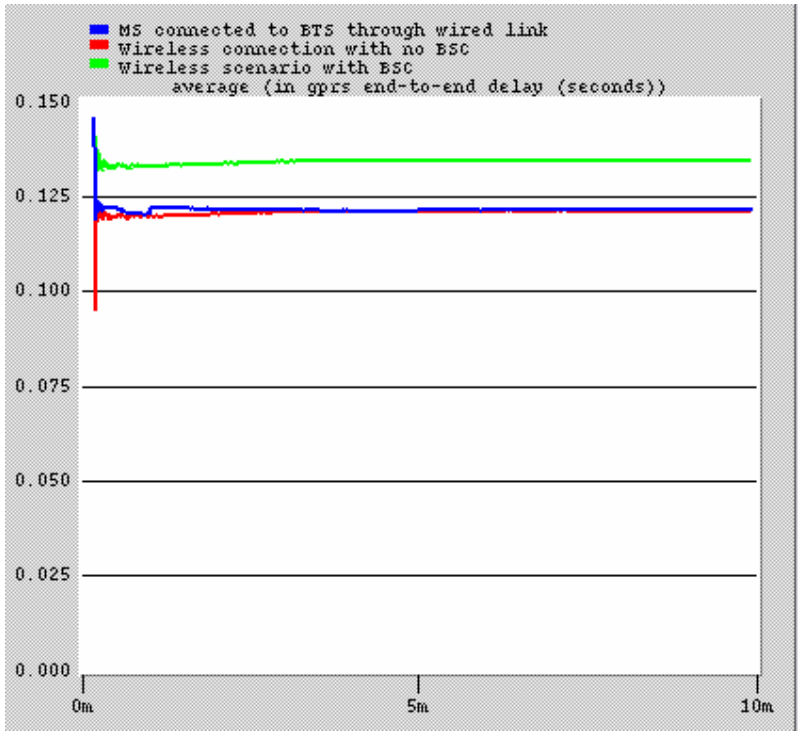


- The collected statistics indicate that a packet has been using either Service Access Point (SAP) 1 or 3 when traversing the LLC layer.
- Initial and final control messages are sent through LLE1 and data traffic in between is sent through LLE3.
- The simulation proves that the control messages (GMM) and user data (SNDCP) are correctly multiplexed onto separate SAPs.

Verification of BSS implementation

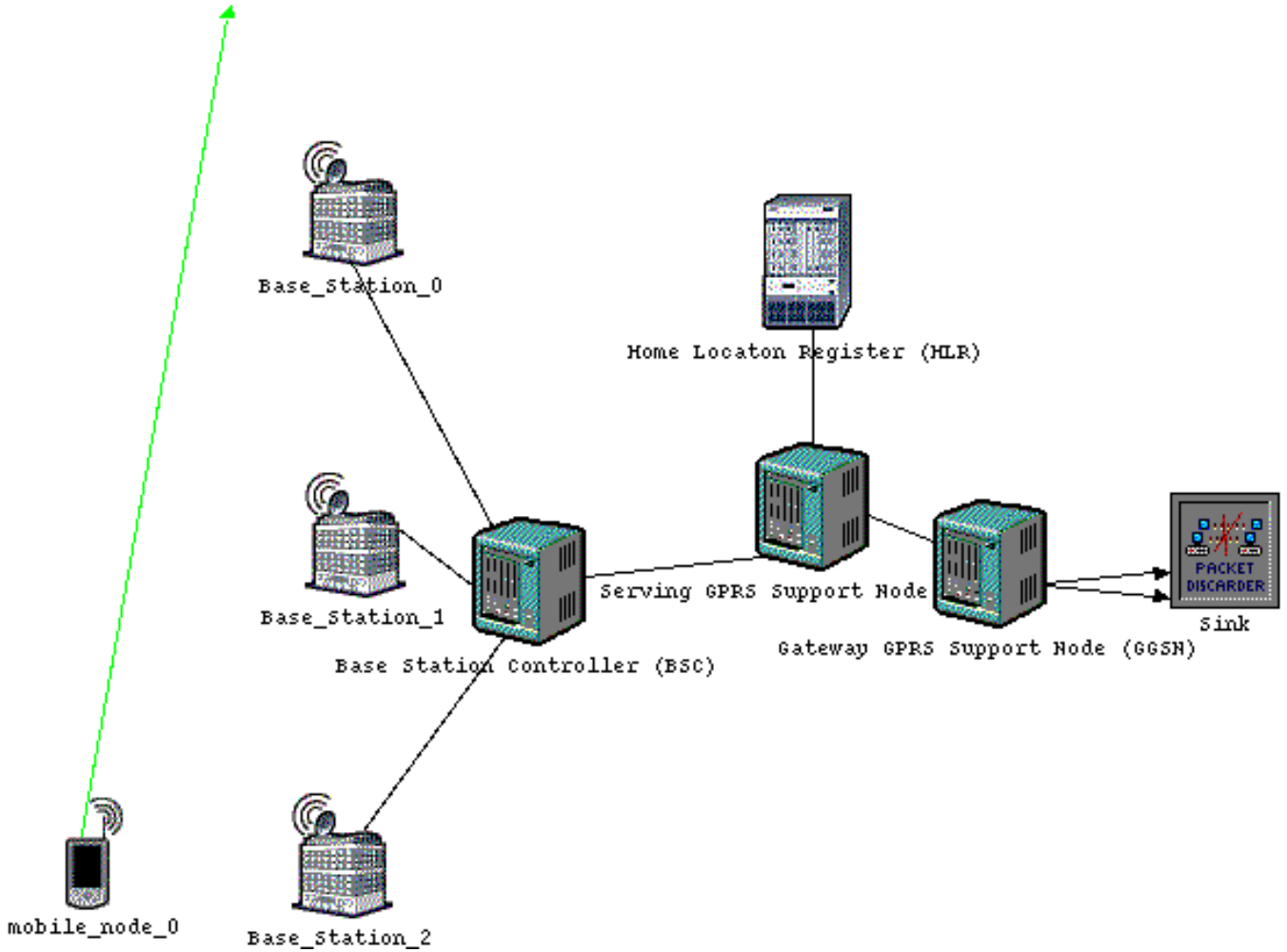
- We simulated three different scenarios:
  - single MS connected to BTS with a wired link and without a BSC
  - wireless scenario without a BSC
  - wireless scenario with a BSC.
- In order to verify the implementation of the wireless connection and the BSC, we measure the packet end-to-end delay from the mobile station to the sink.

Verification of the BSS implementation: results



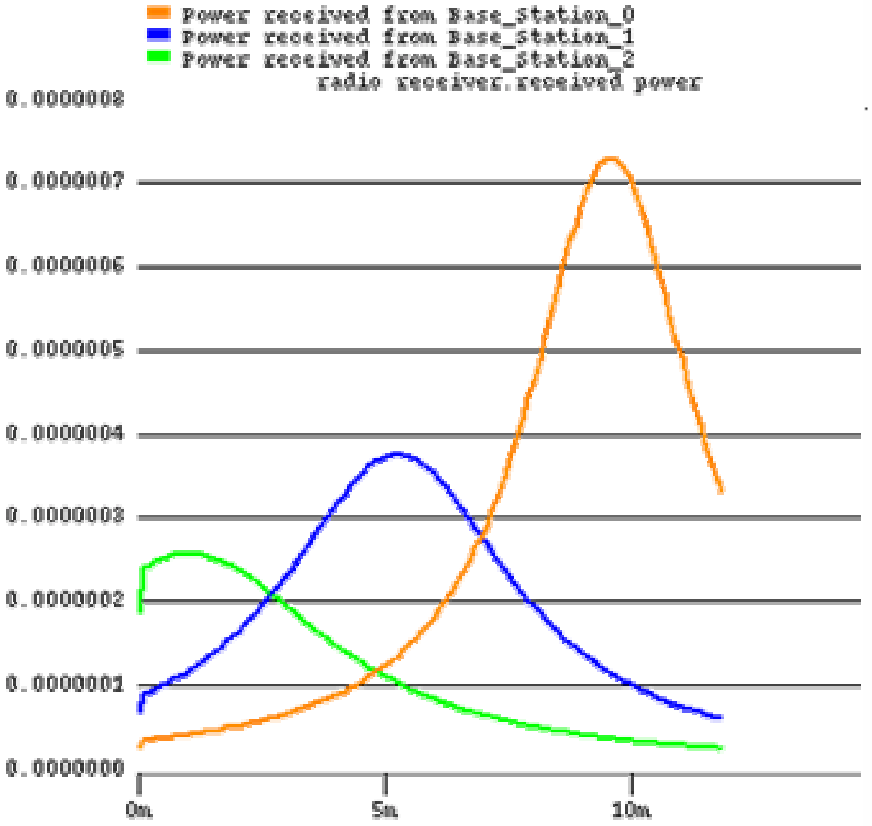
- The end-to-end delay obtained when the MS was connected to the SGSN through a BSC is the largest.
- The reason is the delay imposed by the BSC in receiving, processing, and routing packets.

Simulation of cell update with 1 MS: project model

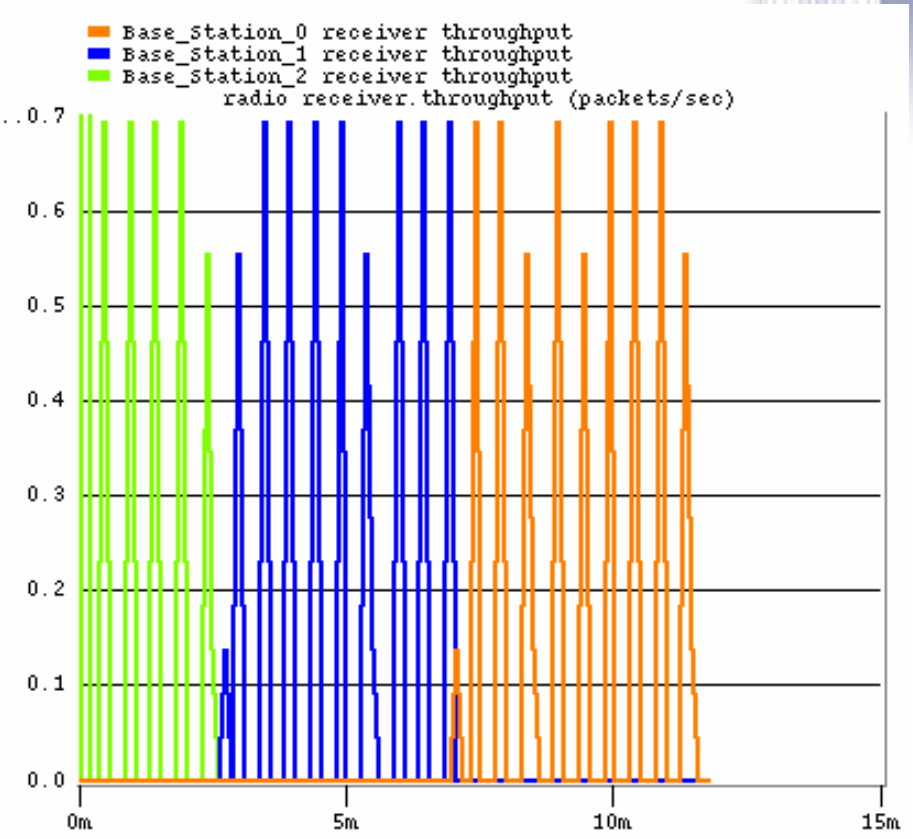


Simulation of cell update with 1 MS: results

- Power received by the MS:

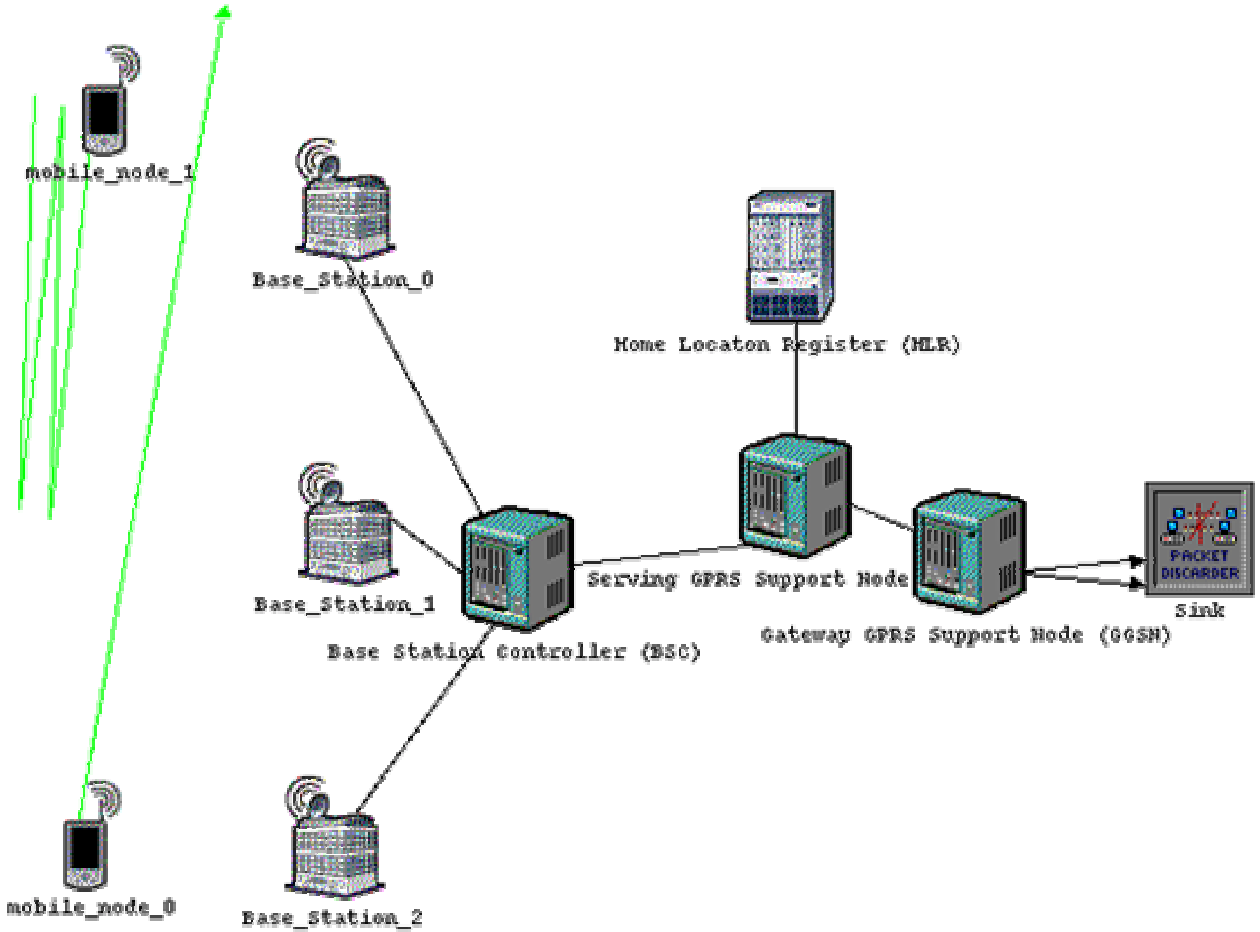


- Throughput at the BTSs:



- Simulation results verify that the cell update has been performed successfully.

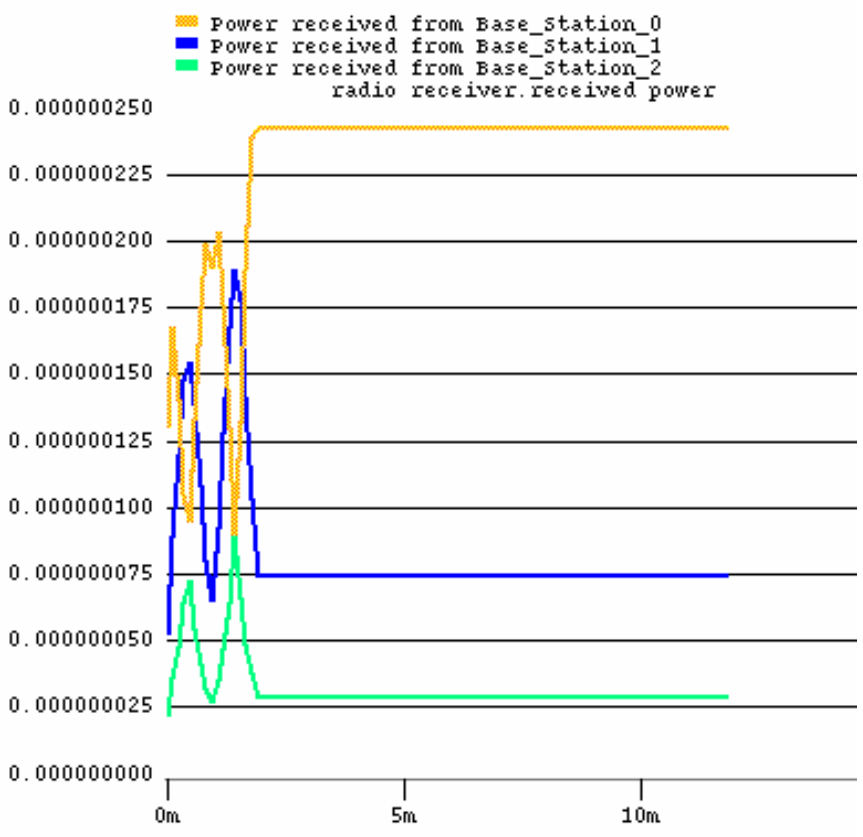
Simulation of cell update with 2 MSs: project model



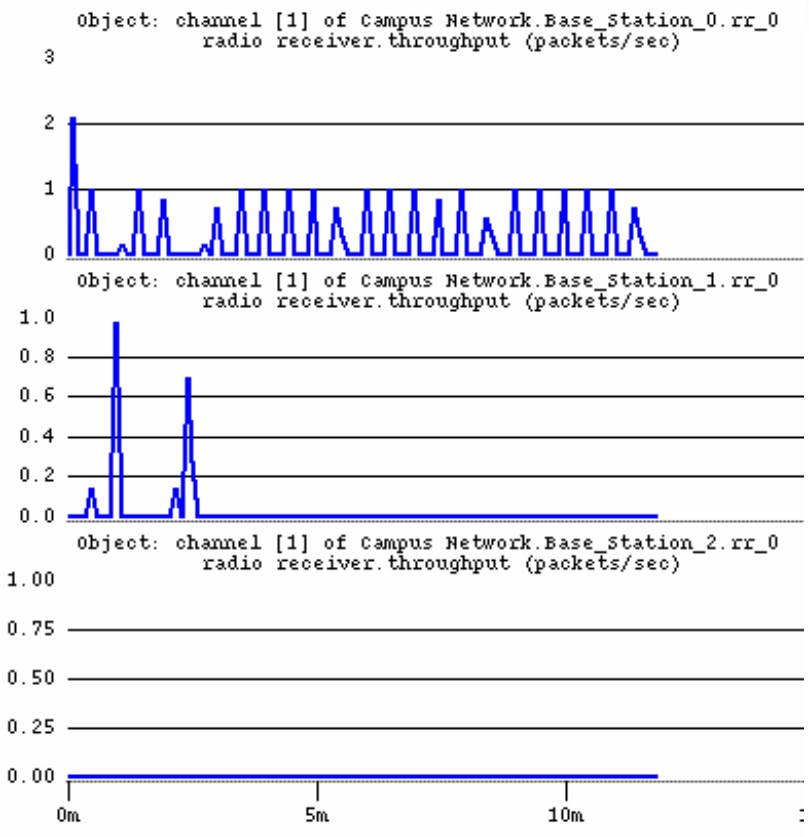
- The MS mobile_node_1 moves between Base_Station_0 and Base_Station_1 only.

Simulation of cell update with 2 MSs: results

- Power received by mobile_node_1:

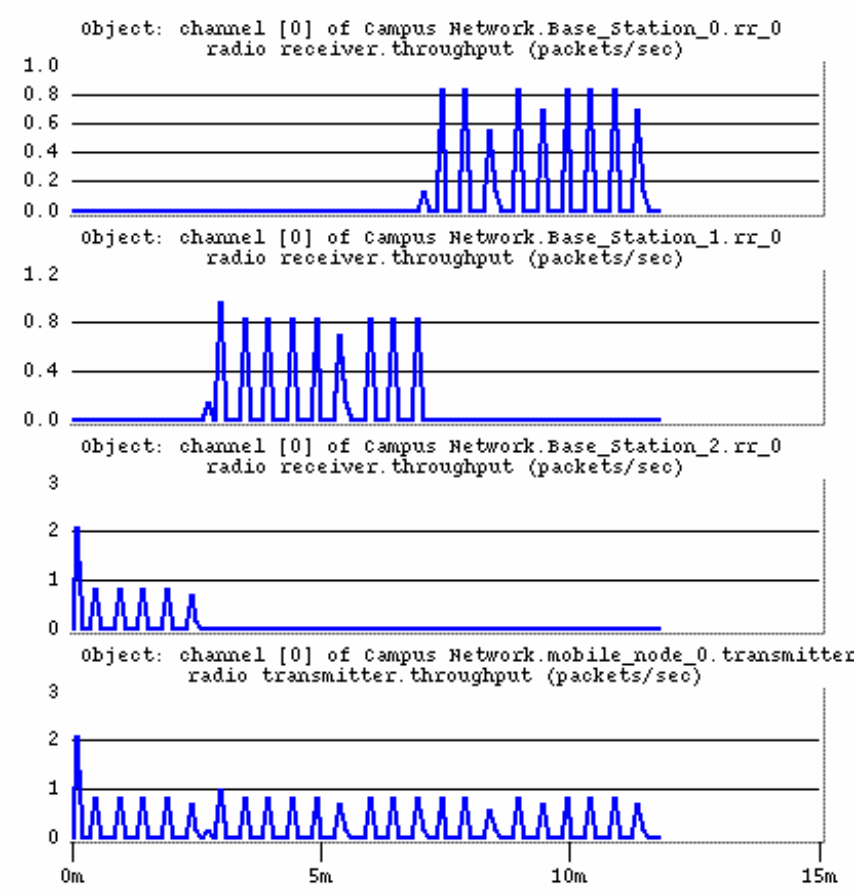


- Channel 1 receiver throughput at the BTSs:



Simulation of cell update with 2 MSs: results

- Channel 0 receiver throughput at the BTSs and transmitter throughput of mobile_node_0:



- Simulation results verify that the channel allocation and routing at the BTSs are implemented correctly.
- Cell update works in the presence of multiple MSs.

Conclusions

- We implemented LLC layer and Base Station Subsystem (BSC and BTS) in an existing OPNET model for GPRS.
- We made several modifications to the existing OPNET model and implemented an autonomous cell update procedure.
- Various simulation scenarios demonstrated that the implementations were done correctly.
- The enhanced GPRS model (release 10.0.A PL2) has been uploaded to the OPNET Contributed Model Depot.

Future work

- Further improve the cell update procedure by introducing cell identifiers.
- Implement the Base Station Subsystem GPRS Protocol (BSSGP).
- Add the Radio Link Control/Medium Access Control (RLC/MAC).
- Employ simulation scenarios using genuine traffic traces.

References

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