General Packet Radio Service OPNET Model

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2G/2.5G/3G Networks II

Roadmap

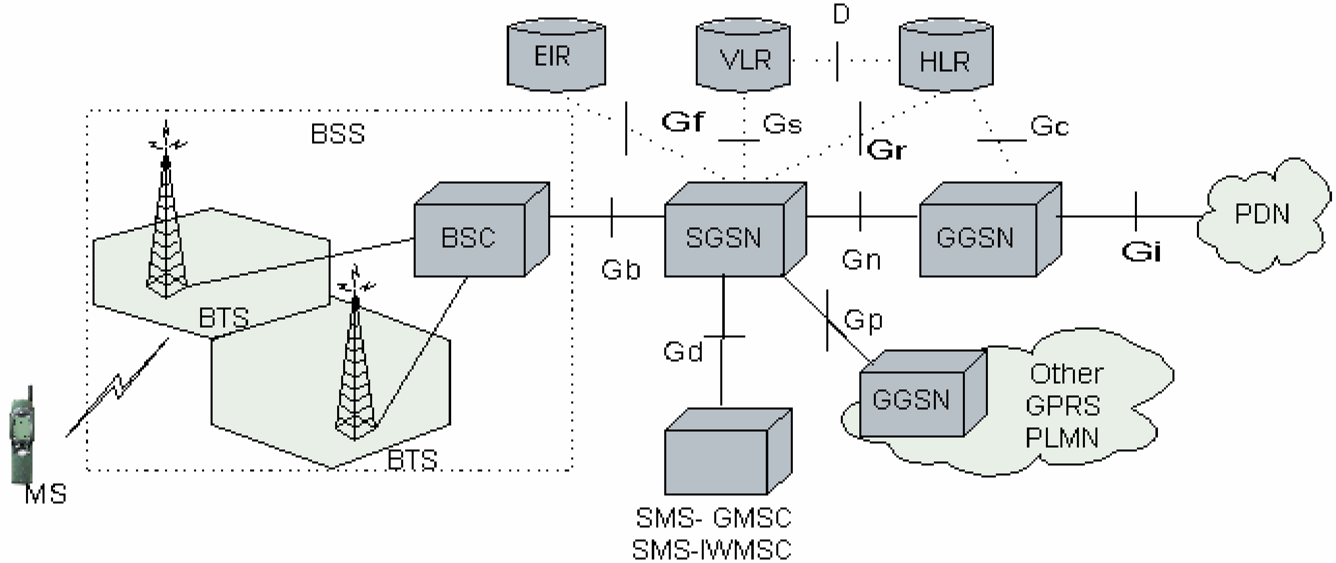
- Introduction
- GPRS air interface
- Radio Link Control/Medium Access Control (RLC/MAC) protocol
- Base Station Subsystem GPRS Protocol (BSSGP)
- GPRS OPNET model:
  - existing model
  - RLC/MAC implementation
  - BSSGP implementation
- Simulation scenarios and results
- Conclusions and future work
- References

Introduction

- General Packet Radio Service (GPRS) was introduced by European Telecommunication Standards Institute
  - Global System for Mobile communications (GSM):
    - Europe: 900 MHz and 1,800 MHz
    - North America: 850 MHz and 1,900 MHz
- Radio channels may be concurrently shared among several users
- Radio resources are allocated when users send or receive data
- Users may always be connected to the network
- Average transmission speeds: 28.8 kbps to 40 kbps
- Billing may be based on traffic volume

TDMA: Time Division Multiple Access

Introduction: GPRS architecture



———— User data and signaling data

············ Signaling data

MS: Mobile Station
BTS: Base Tranceiver Station
BSC: Base Station Controller
BSS: Base Station Subsystem
SGSN Serving GPRS Support Node
GGSN Gateway GPRS Support Node
PDN: Packet Data Network

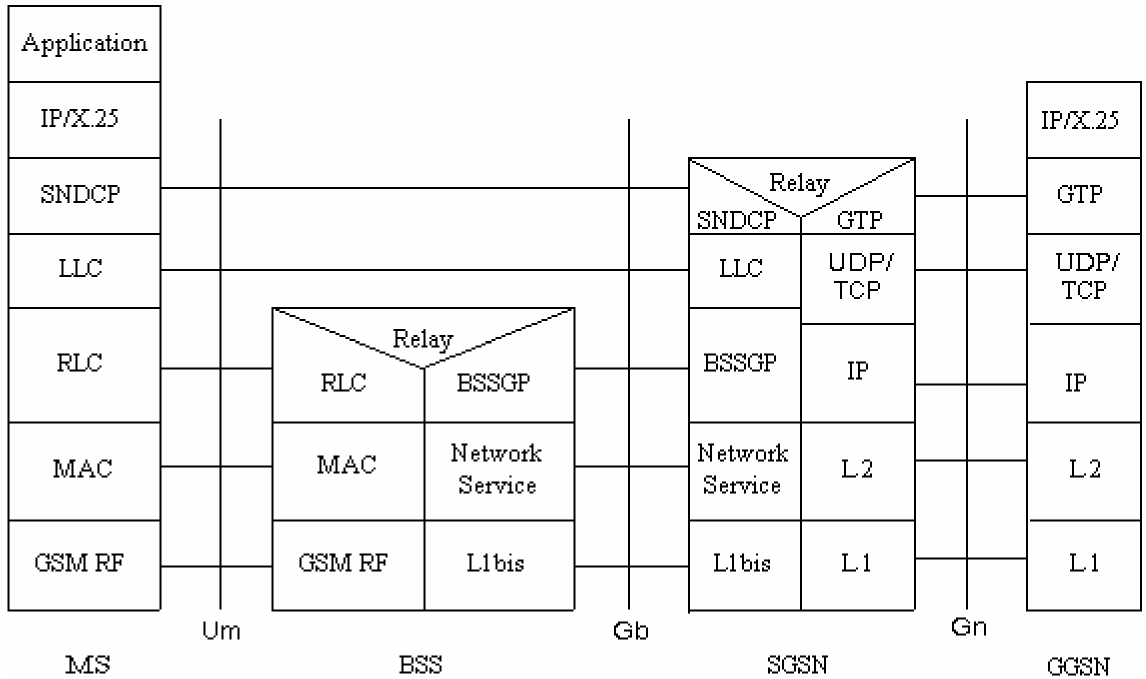
EIR: Equipment Identity Register
VLR: Visitor Location Register
HLR: Home Location Register
SMS: Short Message Service
MSC: Mobile Switching Center
SMS-GMSC: SMS-Gateway MSC
SMS-IWMSC: SMS-Interworking MSC
PLMN: Public Land Mobile Network

Cell update

- Cell update is performed based on the received signal level (RXLEV) measurements performed by MSs
- Three cell update modes:
  - NC0: MS performs autonomous cell reselection and does not send RXLEV measurement reports to the network
  - NC1: MS performs autonomous cell reselection and periodically sends RXLEV measurement reports to the network
  - NC2: network controls cell reselection and the MS sends the RXLEV measurement reports to the network

NC: Network Control

Introduction: GPRS transmission plane



SNDCP: Sub Network Dependent Convergence Protocol
LLC: Logical Link Control layer
RLC: Radio Link Control
MAC: Medium Access Control
BSSGP: Base Station Subsystem GPRS Protocol
GTP: GPRS Tunneling Protocol

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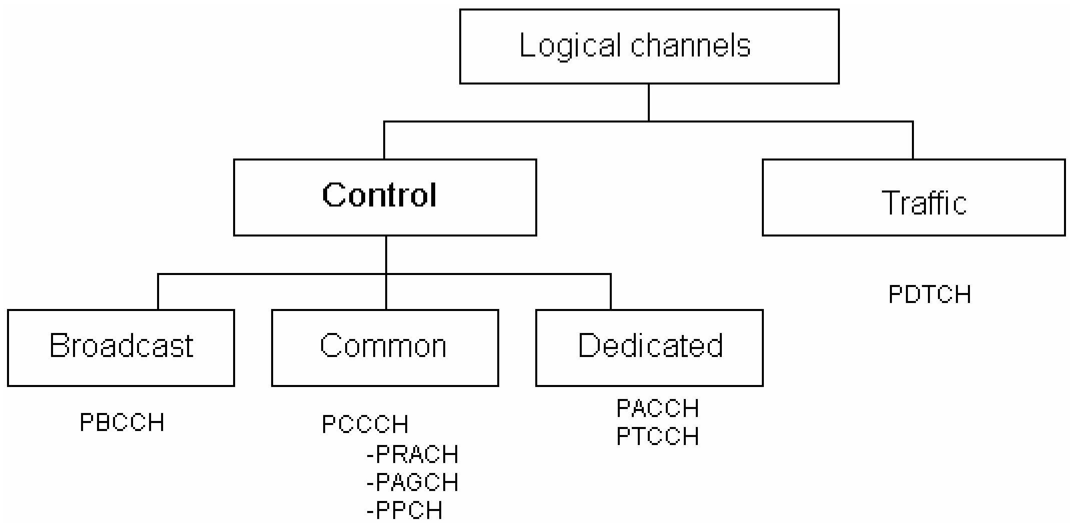
GPRS air interface: unlimited mobility

- Radio channel connection between an MS and a BTS
- Distinct frequencies in uplink (MS to BTS) and downlink (BTS to MS) directions
- Combination of TDMA and FDMA schemes
- Physical channel defined as a radio frequency channel and a time slot pair
- Logical channels mapped onto physical channels
  - Packet Data Channels (PDCHs)
- Four coding schemes: CS-1 to CS-4
  - 9.05 kbps, 13.4 kbps, 15.6 kbps, 21.04 kbps

TDMA: Time Division Multiple Access
FDMA: Frequency Division Multiple Access

Logical channels in GPRS



PBCCH: Packet Broadcast Control Channel
PCCCH: Packet Common Control Channel
PRACH: Packet Random Access Channel
PAGCH: Packet Access Grant Channel

PPCH: Packet Paging Channel
PACCH: Packet Associated Control Channel
PTCCH: Packet Timing Advance Control Channel
PDTCH: Packet Data Traffic Channel

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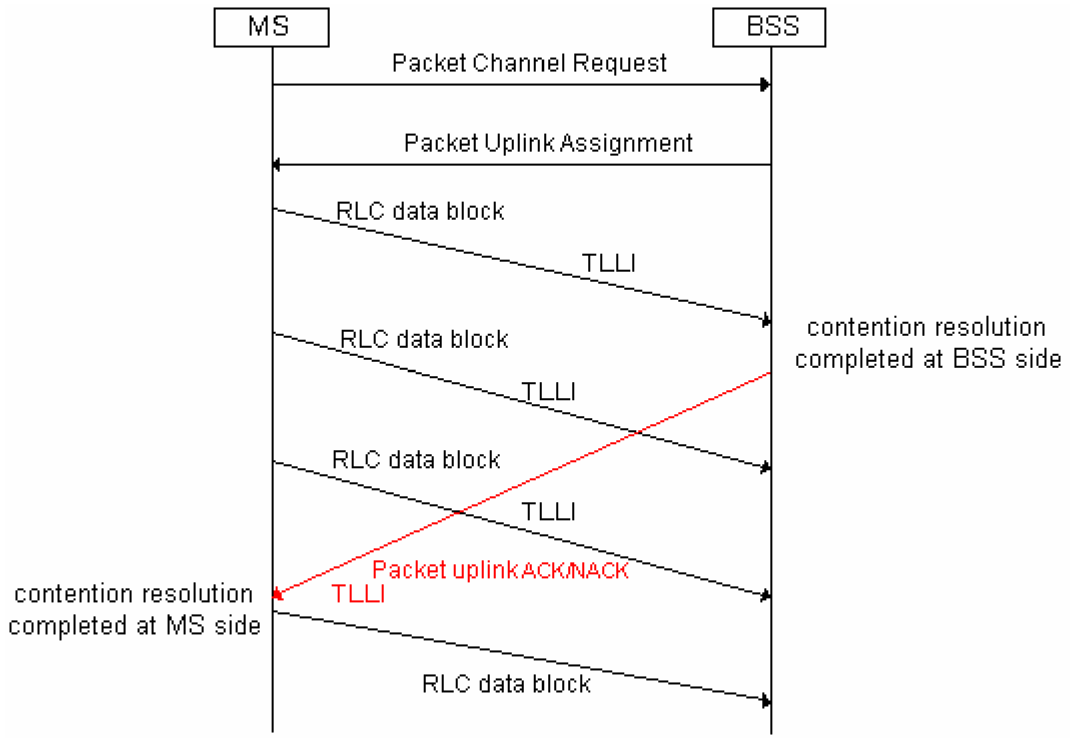
RLC/MAC protocol

- Manages radio resources
- Provides reliable radio link for data transfer between MSs and BTSs
- Multiplexes signaling and data messages from GPRS users
- Provides contention resolution for MS originated data transfers
- Protocol data units (PDUs): RLC/MAC blocks
- Unacknowledged or acknowledged transfer of PDUs
- Temporary Block Flow (TBF) established between two RLC/MAC entities:
  - established for the period of data transfer
  - released immediately after the data transfer
  - Temporary Flow Identity (TFI) assigned to each TBF

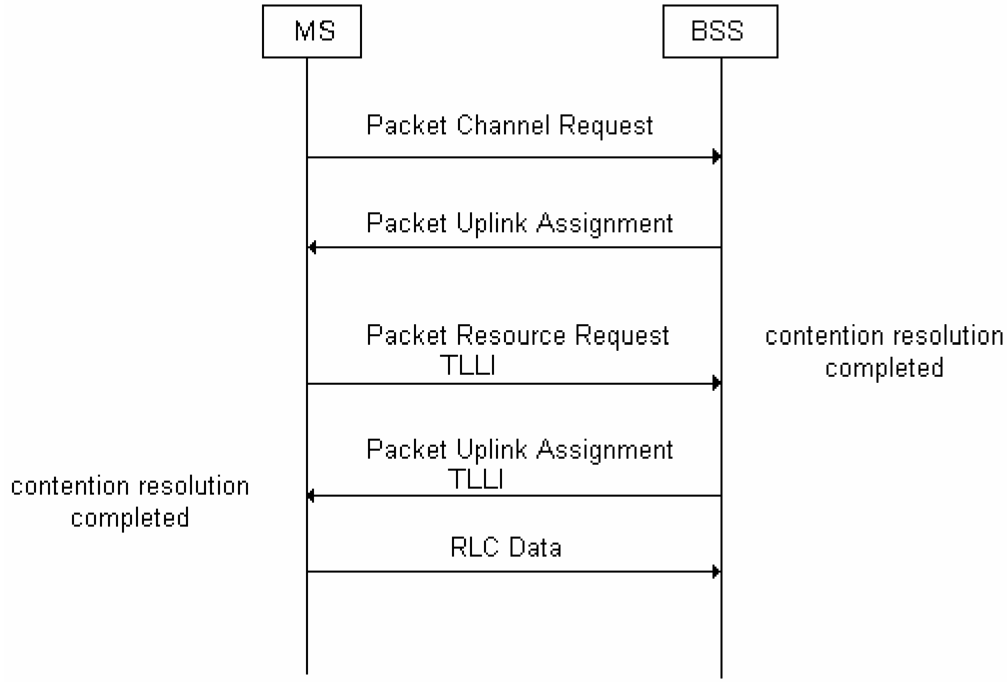
RLC/MAC protocol

- Medium allocation modes:
  - fixed: fixed allocation of radio blocks and PDCHs to the MS
  - dynamic: dynamic allocation of radio blocks using uplink state flag (USF)
  - extended dynamic: dynamic allocation of a range of radio blocks using USF
- GPRS network may support fixed or dynamic allocation mode
- Procedures for uplink TBF establishment:
  - one-phase access procedure: number of resources required is indicated in a channel request message
  - two-phase access procedure: number of resources required is indicated in a packet resource request message

One-phase access procedure



Two-phase access procedure



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Base Station Subsystem GPRS Protocol (BSSGP)

- Controls the transfer of upper layer PDUs between an MS and an SGSN
- Service primitives provided at the BSS to control the transfer of PDUs between RLC/MAC and BSSGP:
  - RL–DL–UNITDATA
  - RL–UL–UNITDATA
  - RL–PTM–UNITDATA
- Service primitives provided at an SGSN to control the transfer of PDUs between the SGSN and BSC:
  - BSSGP–DL–UNITDATA
  - BSSGP–UL–UNITDATA
  - BSSGP–PTM–UNITDATA

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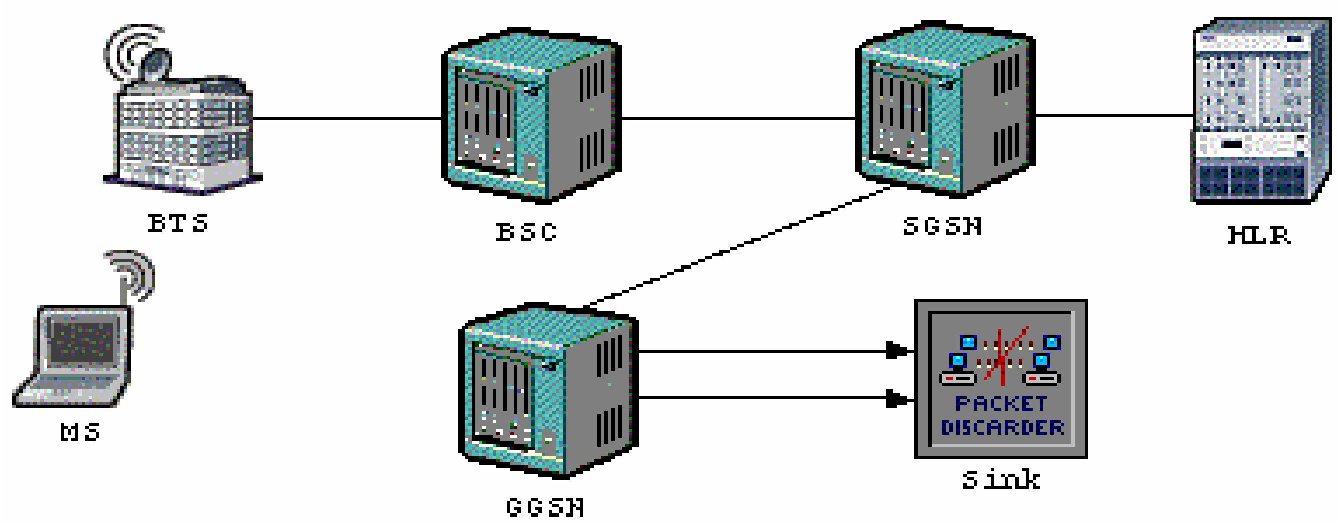
GPRS OPNET model: existing model

- Includes models for:
  - MS, BTS, BSC, SGSN, GGSN, HLR, and a sink
- The sink acts as an external packet data network (PDN)



GPRS OPNET model: existing model

- Existing GPRS model supports:
  - unidirectional data flow
  - bi-directional signal flow
  - six BTSs
  - raw traffic generation
  - autonomous cell update: NC0
  - GPRS mobility management procedures: attach, activate, deactivate, and detach
- MSs in the existing model support only GPRS services
- One packet data protocol context per MS

GPRS OPNET model: existing model

- GGSN transmits packets to the external PDN based on two Quality of Service (QoS) mean throughput classes:
  - slow link: mean throughput = 10,000 octets/hour
  - fast link: mean throughput = 20,000 octets/hour
- SGSN employs a first-in-first-out (FIFO) scheme to handle messages

GGSN: Gateway GPRS Support Node
SGSN: Serving GPRS Support Node

Mean throughput class specifies the expected average data transfer rate across the network during the remaining lifetime of a data transfer session

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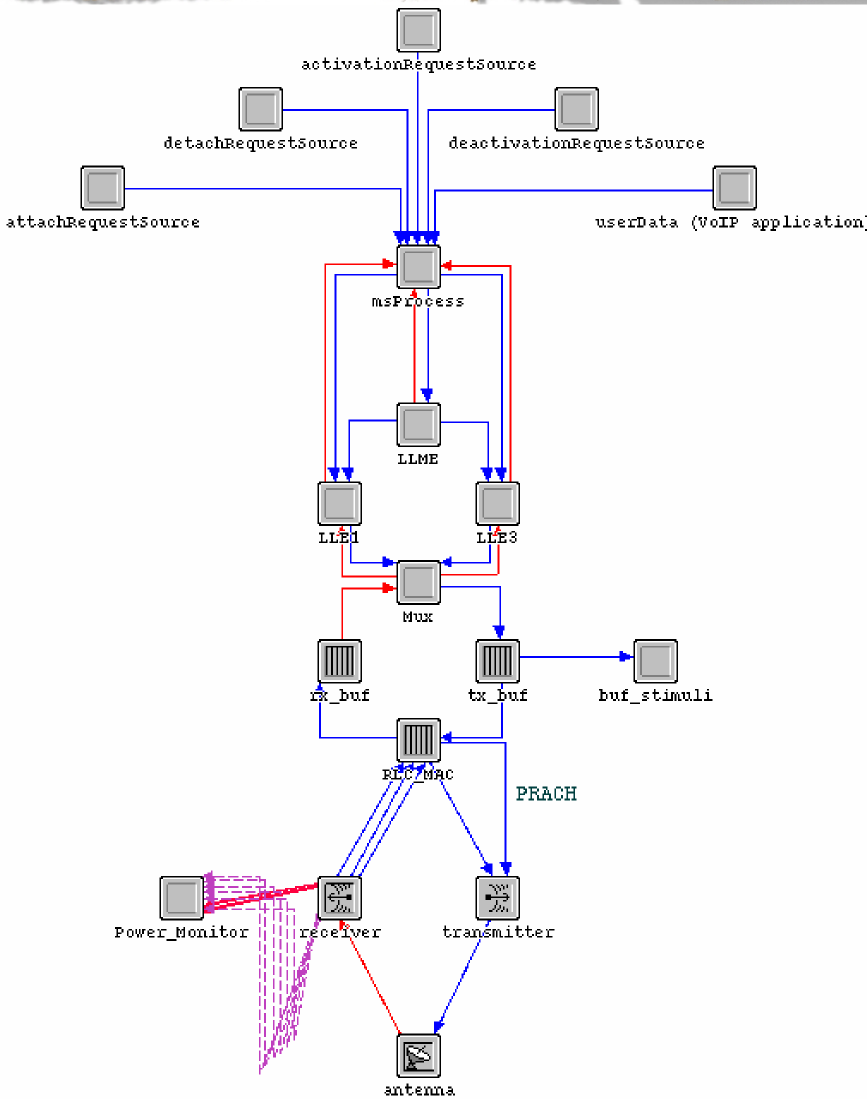
RLC/MAC implementation

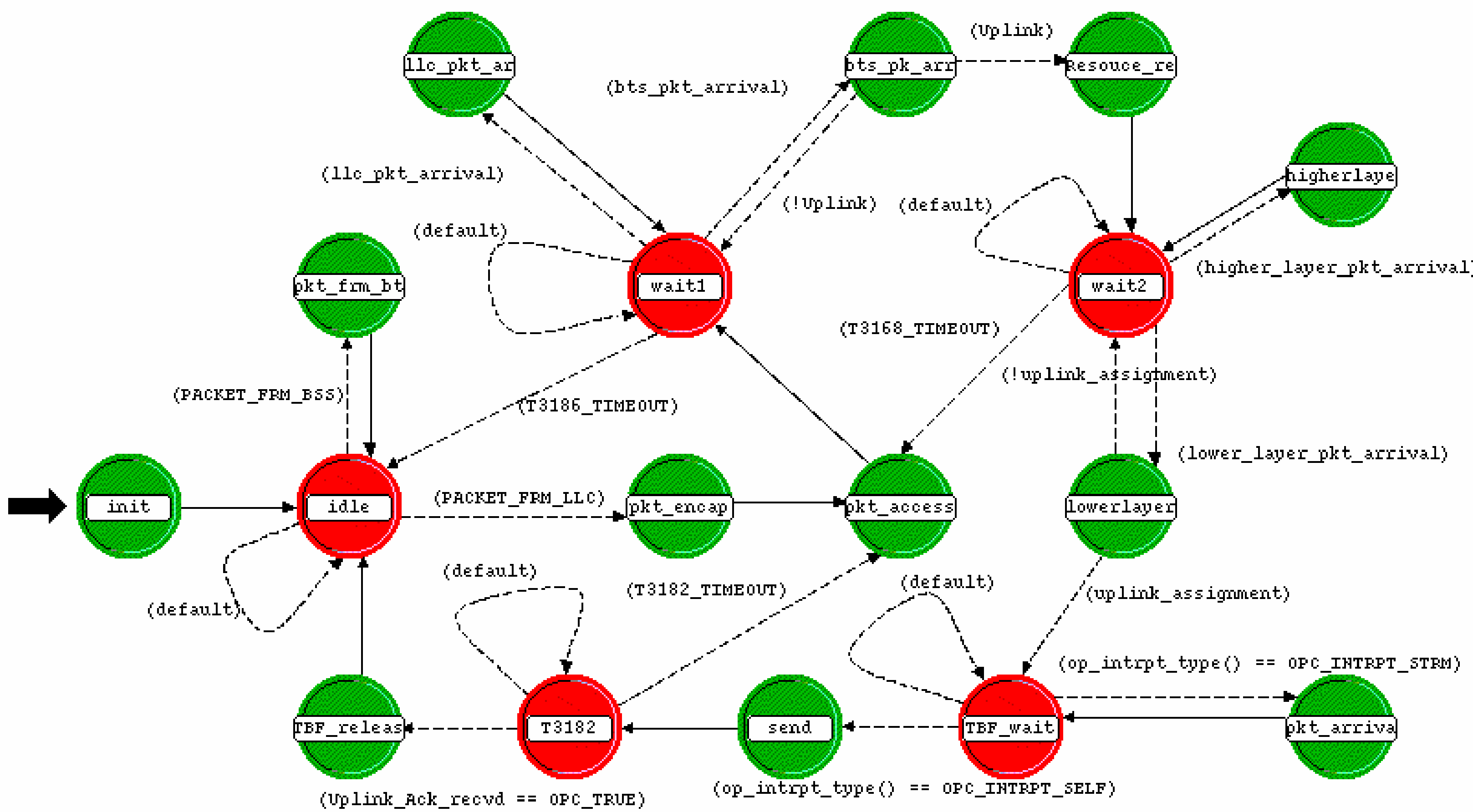
- Unacknowledged RLC mode
- Fixed allocation medium access mode
- Two-phase access procedure
- CS-1 coding scheme: 9.05 kbps
- Dedicated channel for channel requests
- Base station employs a first-in-first-out (FIFO) mechanism to allocate resources

RLC: Radio Link Control

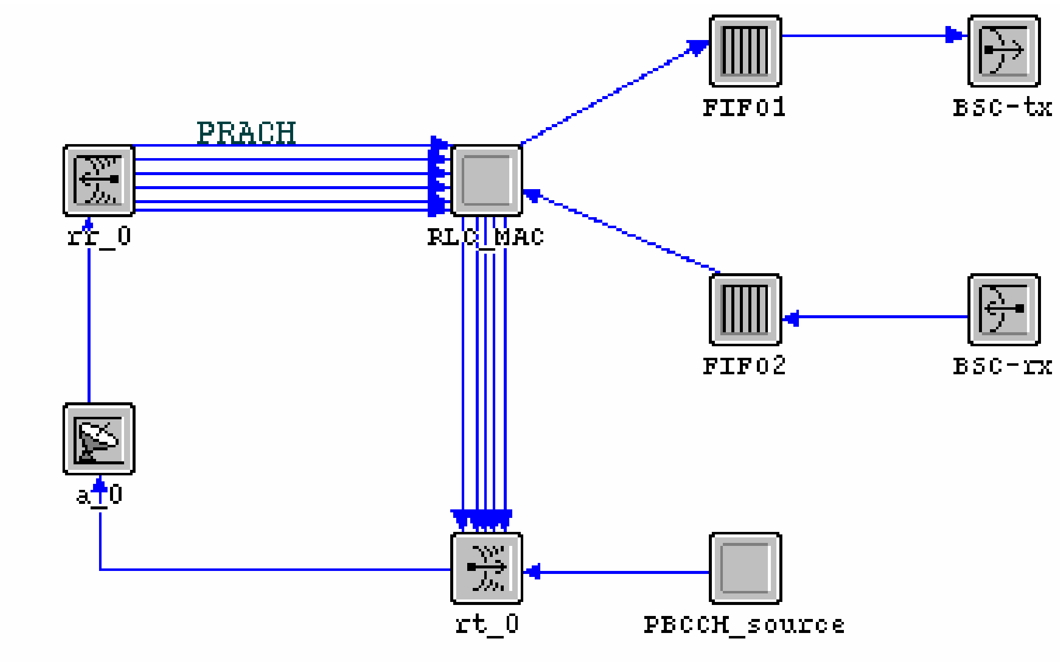
RLC/MAC implementation: MS node model



RLC/MAC implementation: MS process model

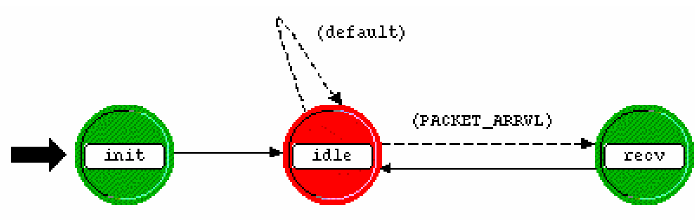


RLC/MAC implementation: BTS node model

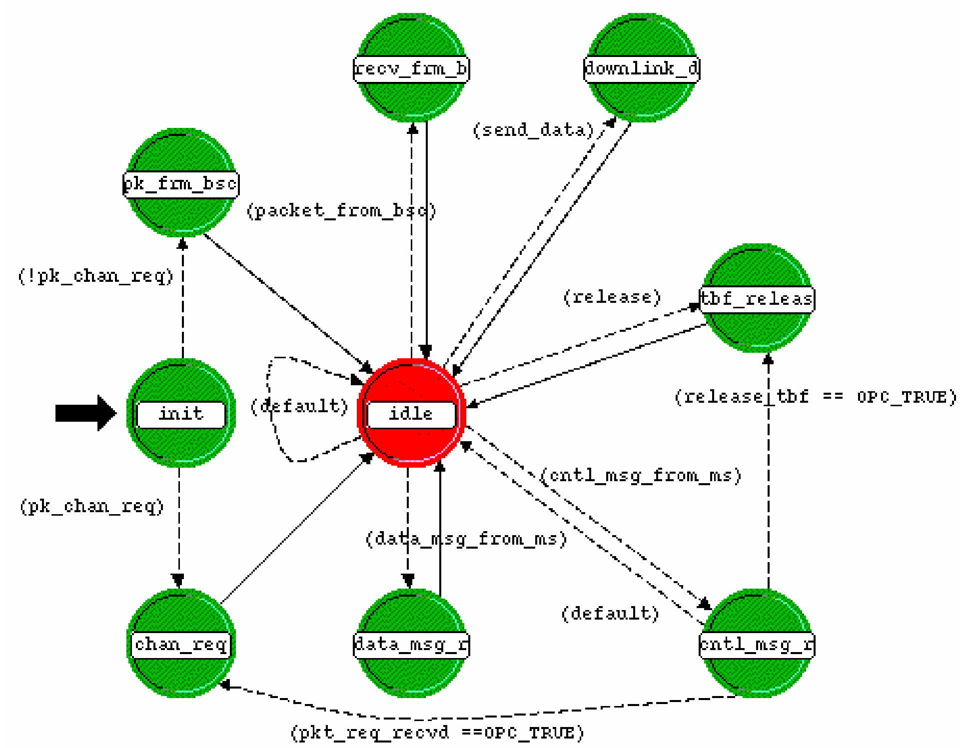


RLC/MAC implementation: BTS process model

Parent BTS process model



Child BTS process model



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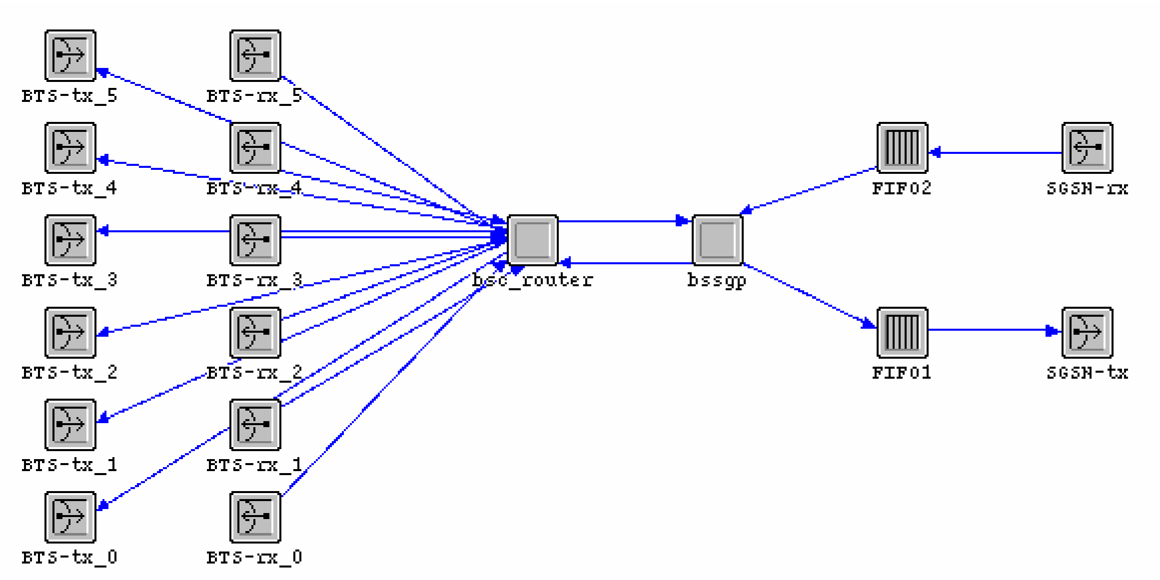
BSSGP implementation

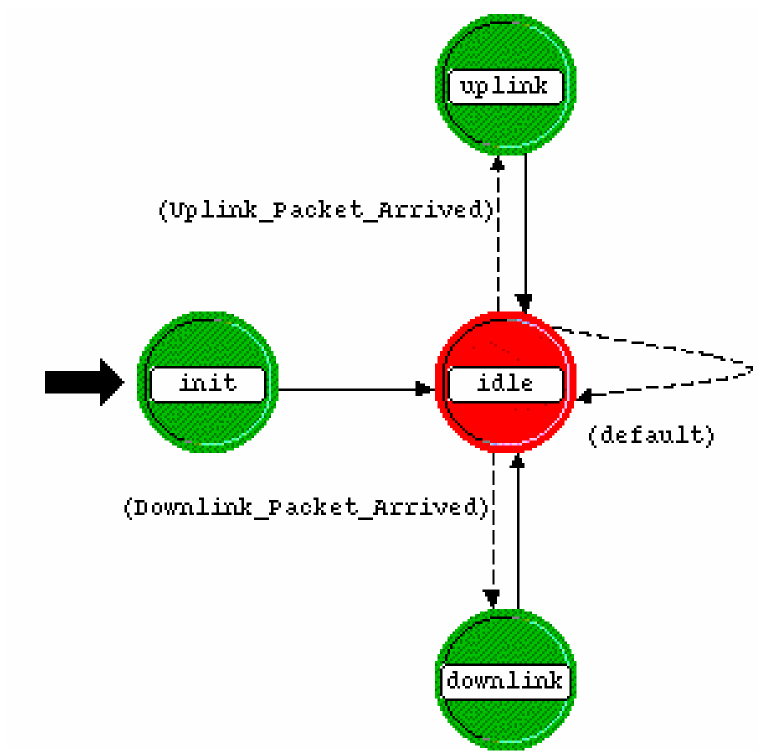
- Service primitives implemented:
  - RL–DL–UNITDATA
  - RL–UL–UNITDATA
  - BSSGP–DL–UNITDATA
  - BSSGP–UL–UNITDATA



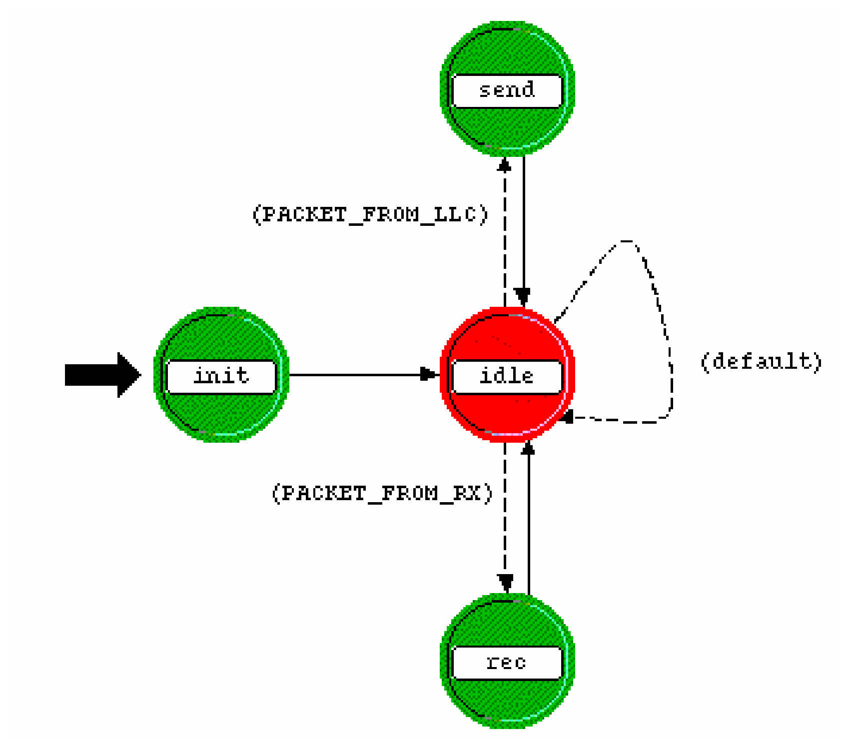
BSSGP node model in BSC

BSSGP process models

Base Station Controller



Serving GPRS Support Node



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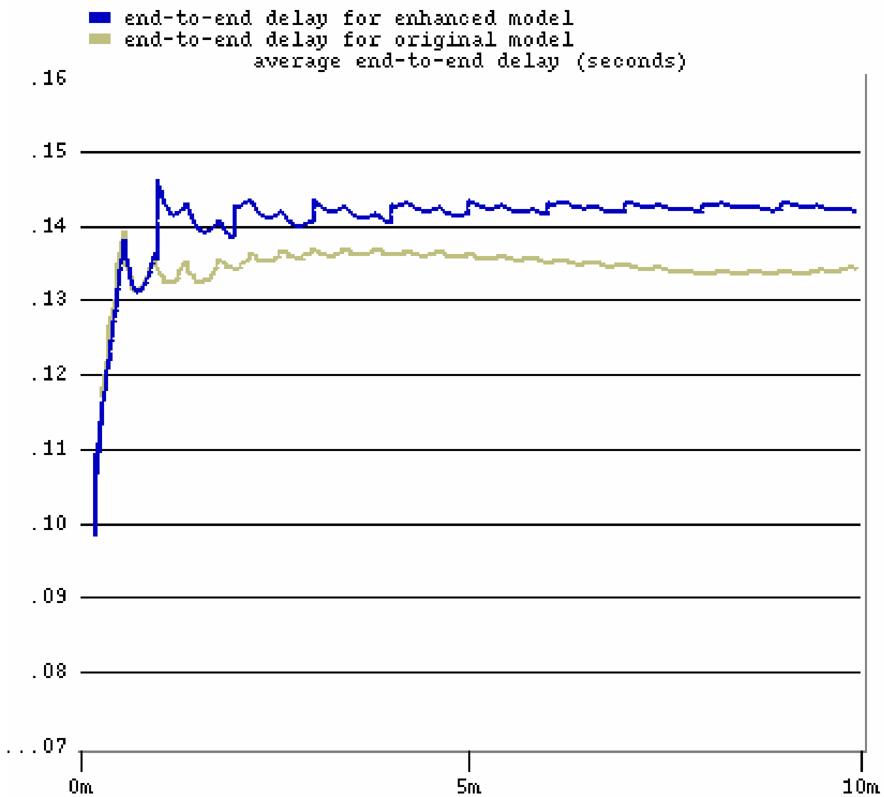
Simulation scenarios and results

- Three simulation scenarios:
  - compare the end-to-end delay experienced with and without the implementation of RLC/MAC and BSSGP protocols
  - verify the cell update procedure
  - verify the scalability of the developed model

End-to-end delay: average packet delay between an MS and the sink

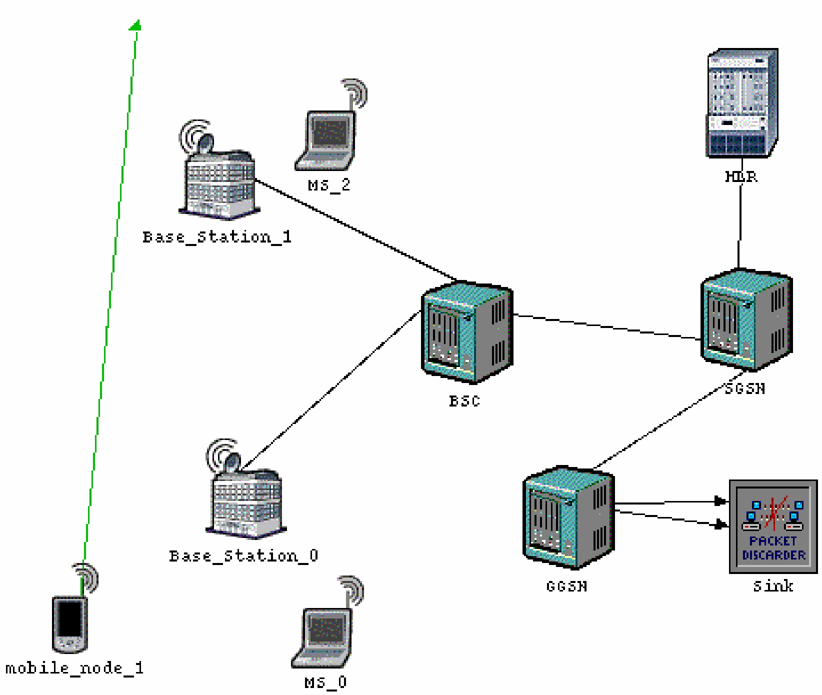
Scenario 1: end-to-end delay

- Two MSs and a BTS
- Simulation time: 10 minutes
- Data transmission rate: constant throughout the simulation

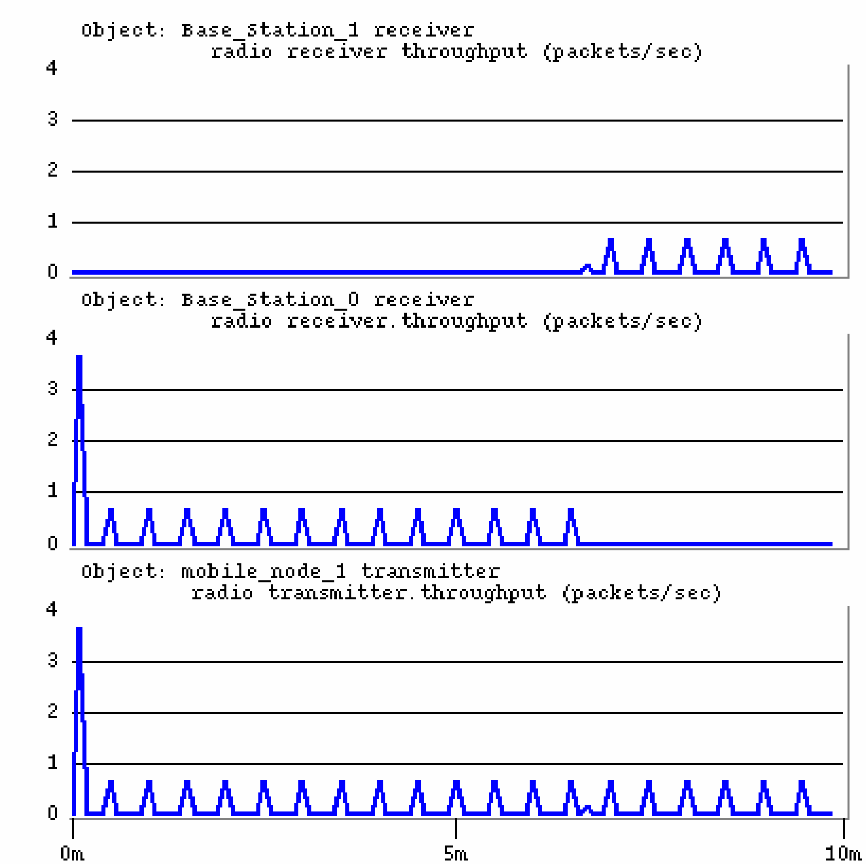


Scenario 2: cell update

Simulation scenario



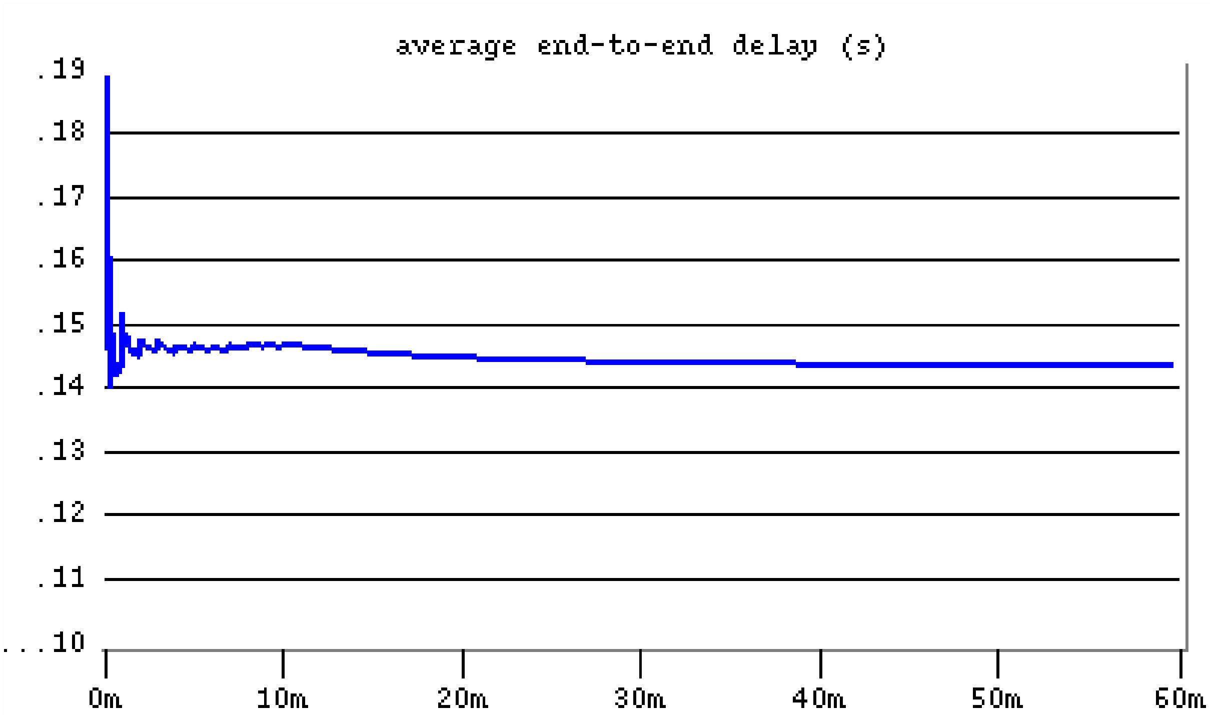
Throughput at the MS and BTSs transceivers



Scenario 3: scalability

- 17 MSs and 3 BTSs
  - 11 MSs generate variable bit rate traffic
  - 6 MSs generate constant bit rate traffic
- Generate traffic at the beginning of simulation (0 s)
- Simulated time: 1 hour
  - simulations lasted 40 minutes
- Measured average end-to-end packet delay

Scenario 3: average end-to-end delay



End-to-end delay increases and reaches steady-state

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Conclusions and future work

- We developed an OPNET model for GPRS
- The model implemented various GPRS-specific protocols
- We presented implementation of two additional protocols in an existing GPRS model:
  - RLC/MAC
  - BSSGP
- Three simulated scenarios were used to verify the model implementation
- Additional simulations need to be performed in order to explore the model scalability

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Questions?