Simulation of General Packet Radio Service Network

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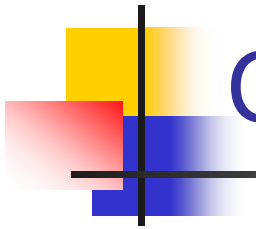


Credits

- Ricky Ng, M.Eng. project
- OPNETWORK 2002, Washington DC, August 2002.

Road map

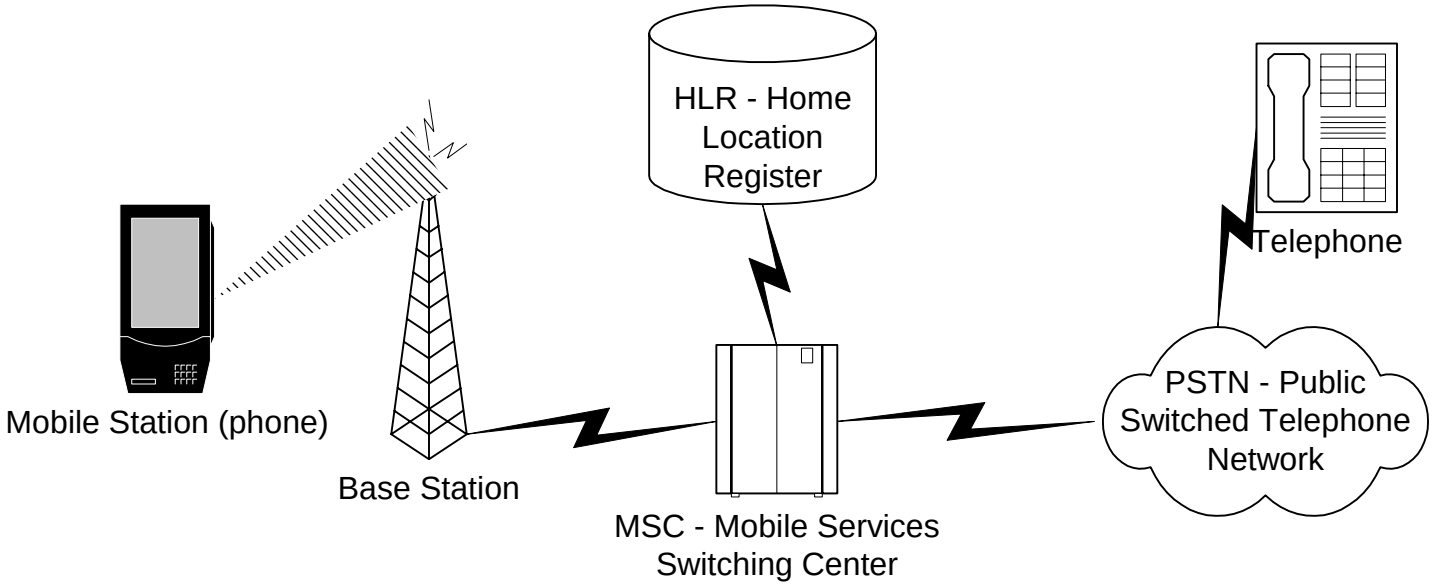
- Introduction to GSM and GPRS networks
- Project goals
- OPNET model implementation
- Simulation scenarios
- Simulation results
- Conclusions

What is GSM?

- Stands for Global System for Mobile communication
- Basic service was launched in 1992 to standardize cellular systems in Europe
- Basic bandwidth:
  - 900 MHz and 1800 MHz (Europe and Asia)
  - 1900 MHz (North America)
- Access technology: TDMA/FDMA

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

GSM network


HLR - Home Location Register
Telephone
Mobile Station (phone)
Base Station
MSC - Mobile Services Switching Center
PSTN - Public Switched Telephone Network

Data over GSM

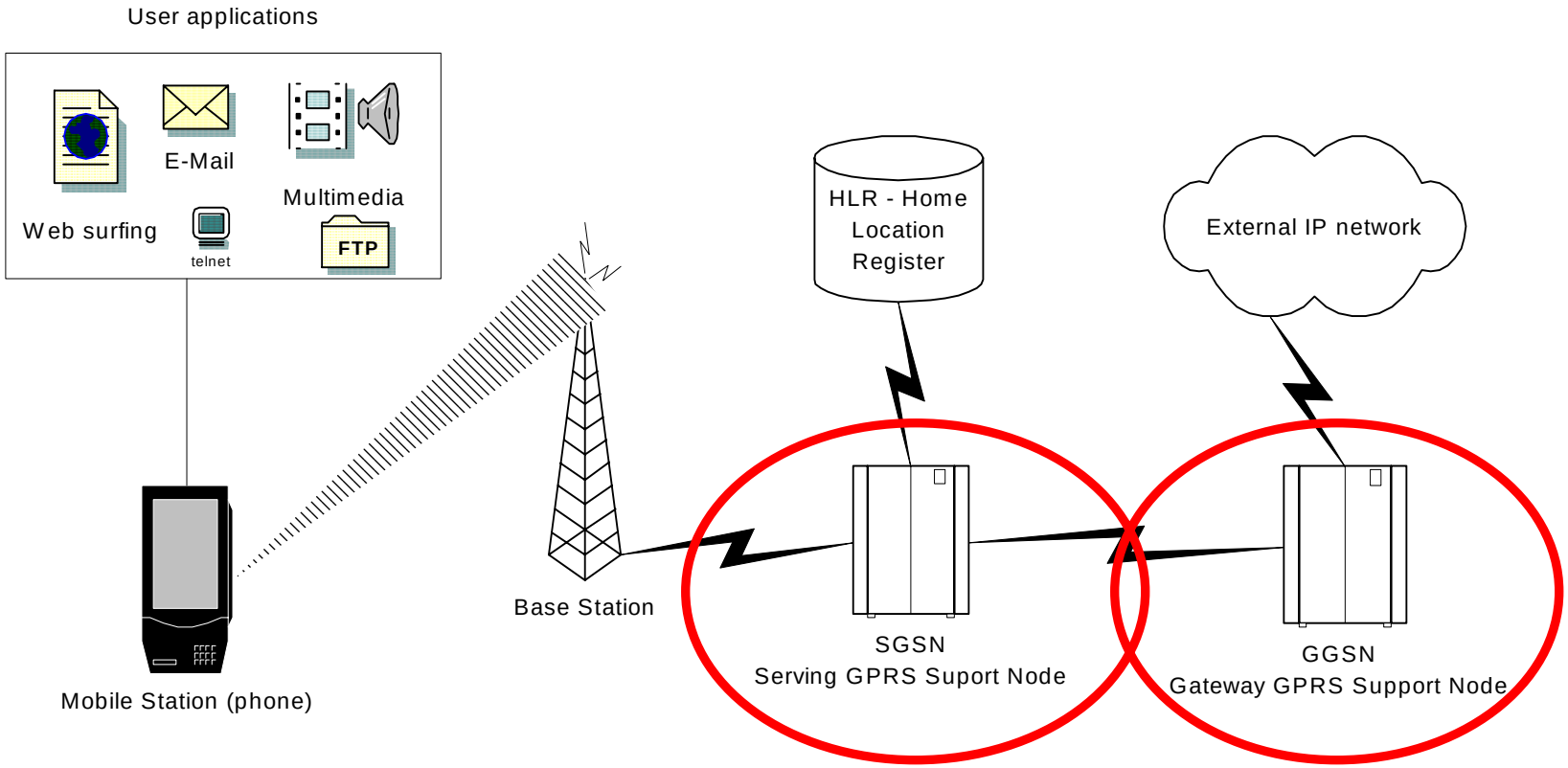
- Circuit-switched network is good for voice service, but not for data transfers
- Billing is based on a connection time
- Entire radio channel is dedicated to a single user
- Inefficient resource allocation for bursty data transmissions results in:
  - slow data transmission: 9.6 kbps

Solution: GPRS

- A data service that provides:
  - packet switched routing infrastructure functionality
  - packet radio access for mobile stations
- Radio channels can be concurrently shared between several users
- Up to eight radio interface timeslots can be allocated per TDMA frame, supporting a speed up to 150 kbps
- Average transmission speeds: 28.8 kbps to 40 kbps
- Billing can be based on traffic volume

GPRS: General Packet Radio Service
TDMA: Time Division Multiple Access

GPRS network



GPRS introduces two new nodes

- Serving GPRS Support Node (SGSN)
  - at the same hierarchical level as the MSC
  - keeps track of the location of a mobile station and handles access control
  - connects to Base Station with Frame Relay
  - connects to HLR with a Signalling System no. 7 (SS7) network
- Gateway GPRS Support Node (GGSN)
  - provides interworking with external packet switched networks
  - connects to SGSN with an IP backbone

MSC: Mobile-services Switching Center
HLR: Home Location Register

Project goals

- To model and simulate a GPRS network that supports:
  - basic GPRS procedures:
    - attach and activation
    - user data transmission
    - detach and deactivation
  - two classes of QoS in data transmission rates
  - collection of network performance data

QoS: Quality of Service

Why modeling and simulation?

- Easy to generate test scenarios
- Inexpensive in changing test setup and running test cases
- Data are available to evaluate network performance

OPNET tools

- Node model: specifies interface of a network component
- Packet format: defines protocols
- Process model: abstracts the behavior of a network component
- Project window: defines network topology and link connections
- Simulation window: captures and displays simulation results

New OPNET node model

- OPNET node models define the structure for:
  - Mobile Station
  - Serving GPRS Support Node
  - Gateway GPRS Support Node
  - Internal Home Location Register
  - Sink (external packet network)

New packet format

- OPNET packet formats define protocols between:
  - MS and SGSN
  - SGSN and GGSN
  - SGSN and the Internal HLR

MS: Mobile Station
SGSN: Serving GPRS Support Node
GGSN: Gateway GPRS Support Node
HLR: Internal Home Location Register

New process model

- OPNET process models capture the basic GPRS procedures:
  - attach
  - activation
  - user data transmission
  - deactivation
  - detach

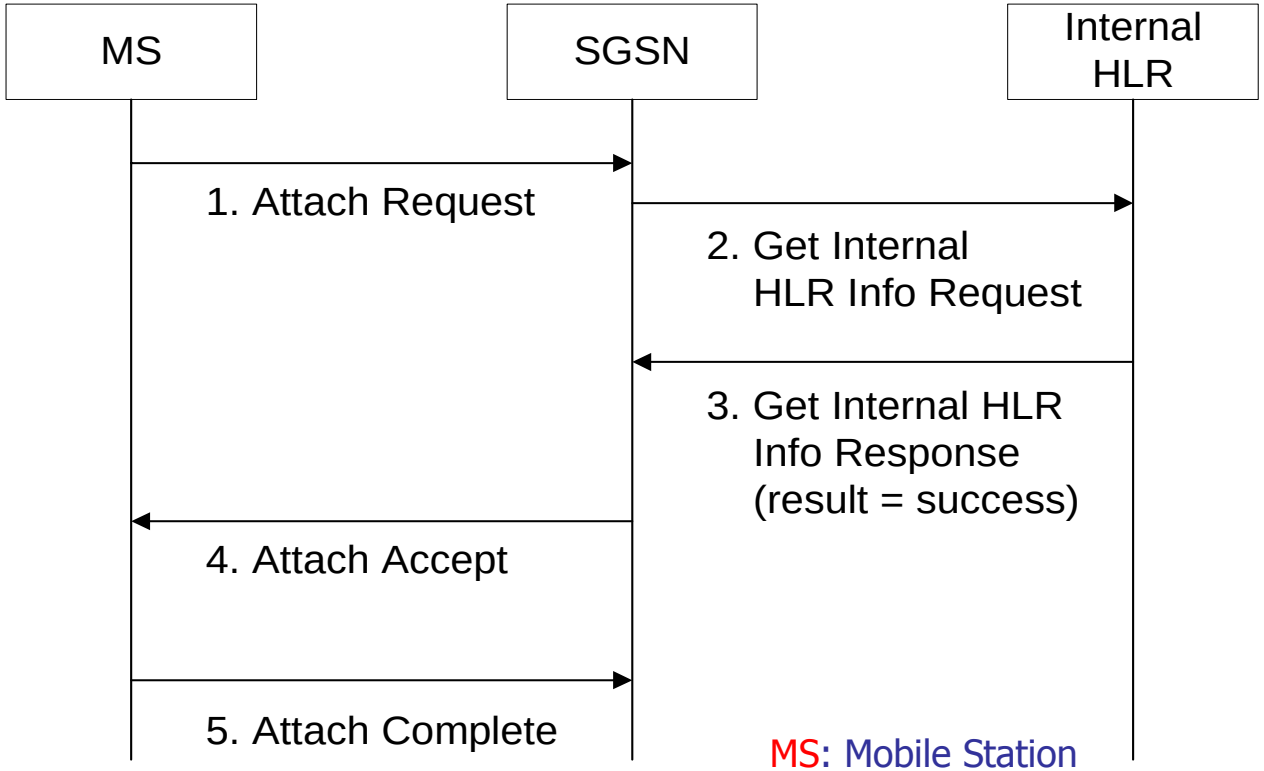
Attach procedure

- MS makes itself known to the GPRS network via Attach
- Once the MS is attached to the network, the network knows the location and capabilities of the MS

MS: Mobile Station

Attach procedure: accepted

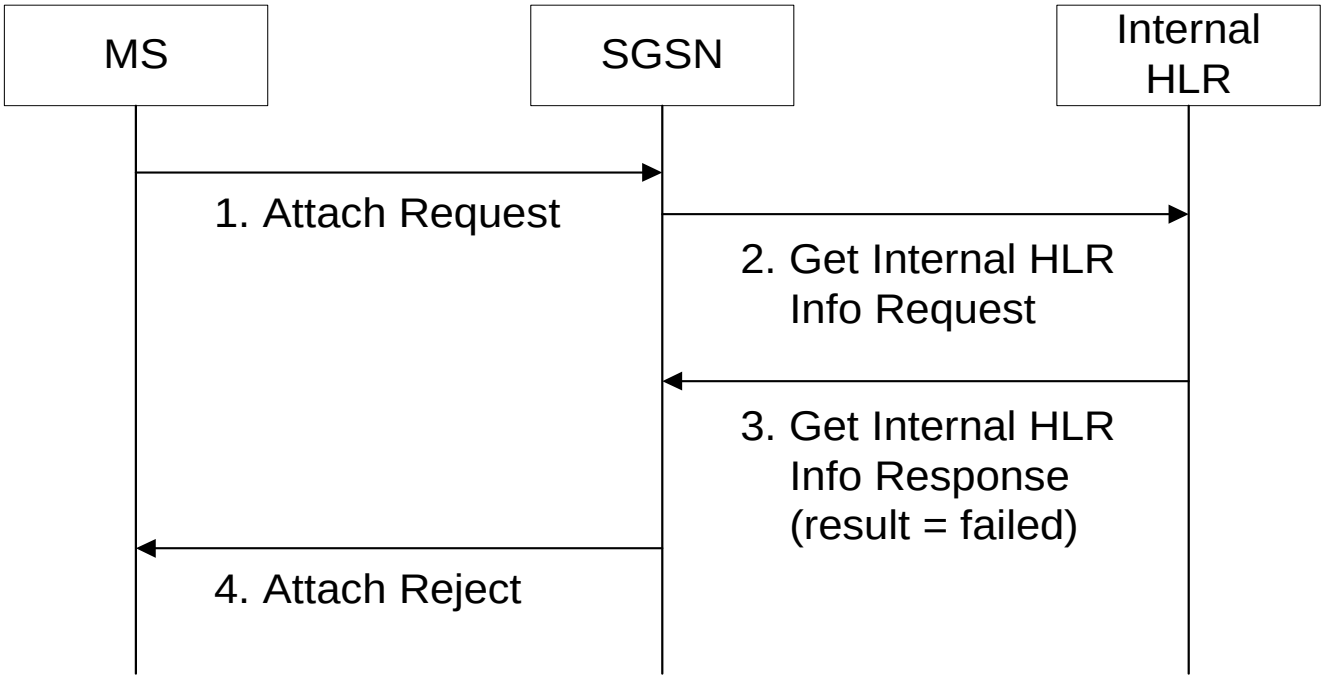
Message sequence chart



MS: Mobile Station
SGSN: Serving GPRS Support Node
HLR: Home Location Register

Attach procedure: rejected

Message sequence chart



MS: Mobile Station
SGSN: Serving GPRS Support Node
HLR: Home Location Register

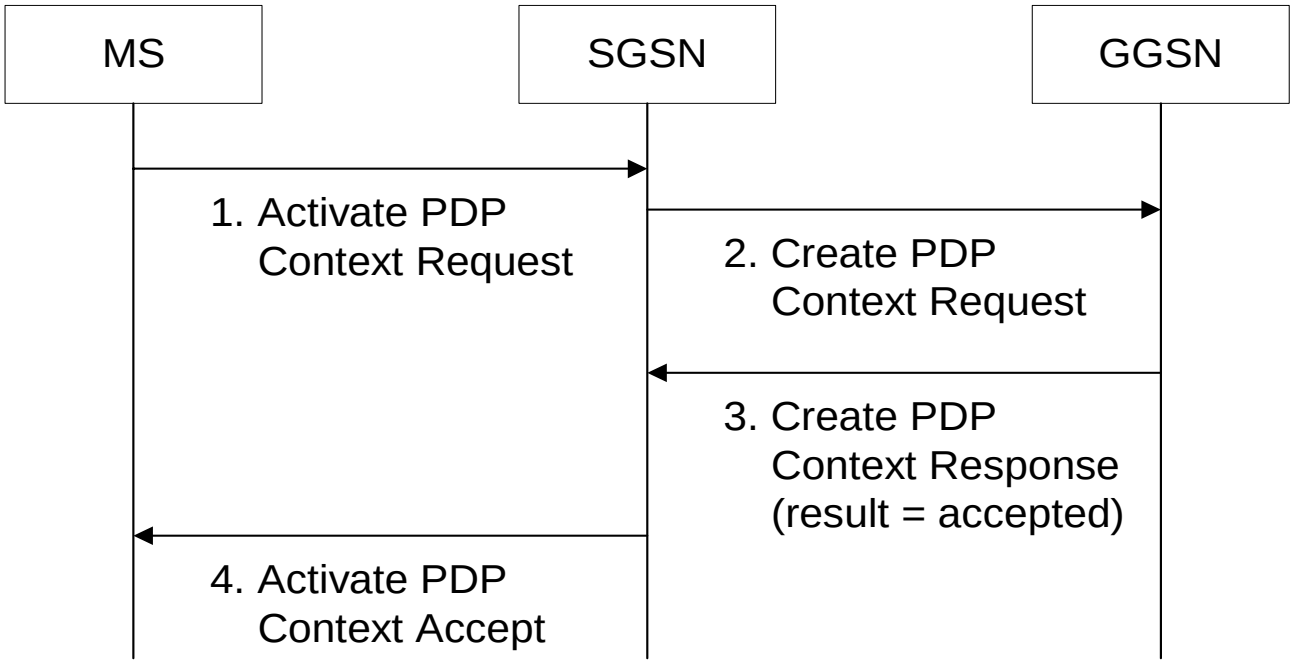
Activation procedure

- Before MS can communicate with sink, the Packet Data Protocol (PDP) context must be activated
- PDP context describes the characteristics of the connection to the sink:
  - requested QoS
  - data session identifier
  - type of external network to which it is connected
- MS can start sending user data once a data session is activated

MS: Mobile Station
QoS: Quality of Service

Activation procedure: accepted

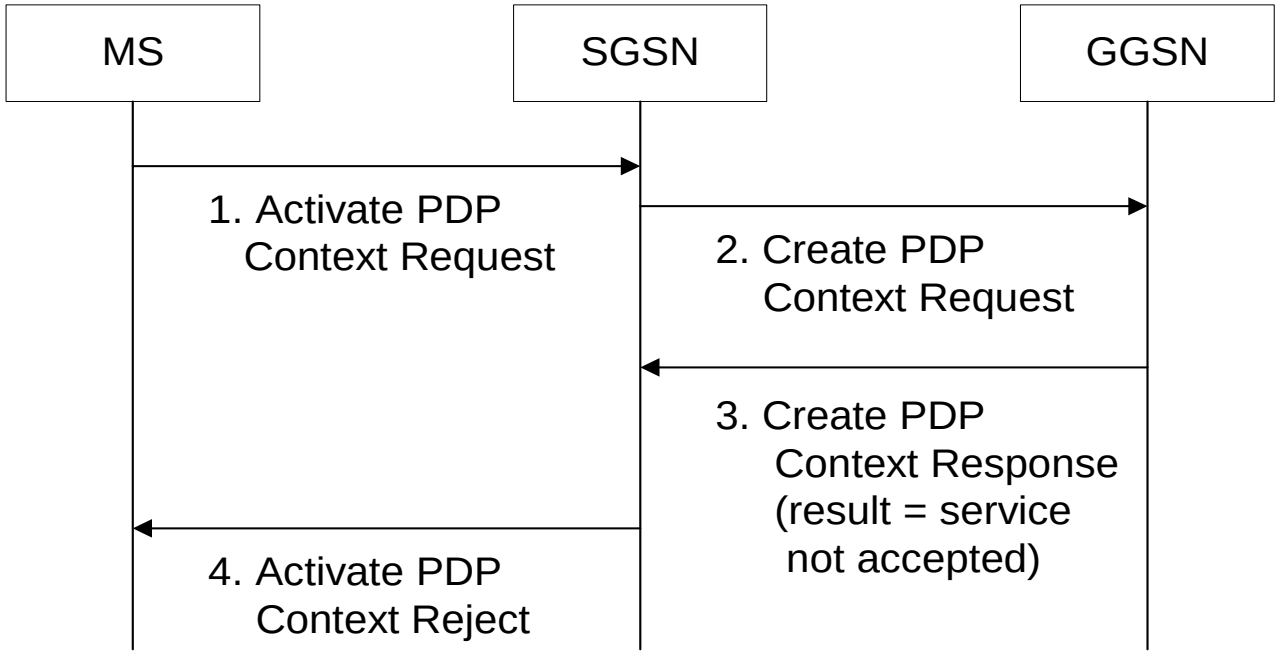
Message sequence chart



MS: Mobile Station
SGSN: Serving GPRS Support Node
GGSN: Gateway GPRS Support Node
PDP: Packet Data Protocol

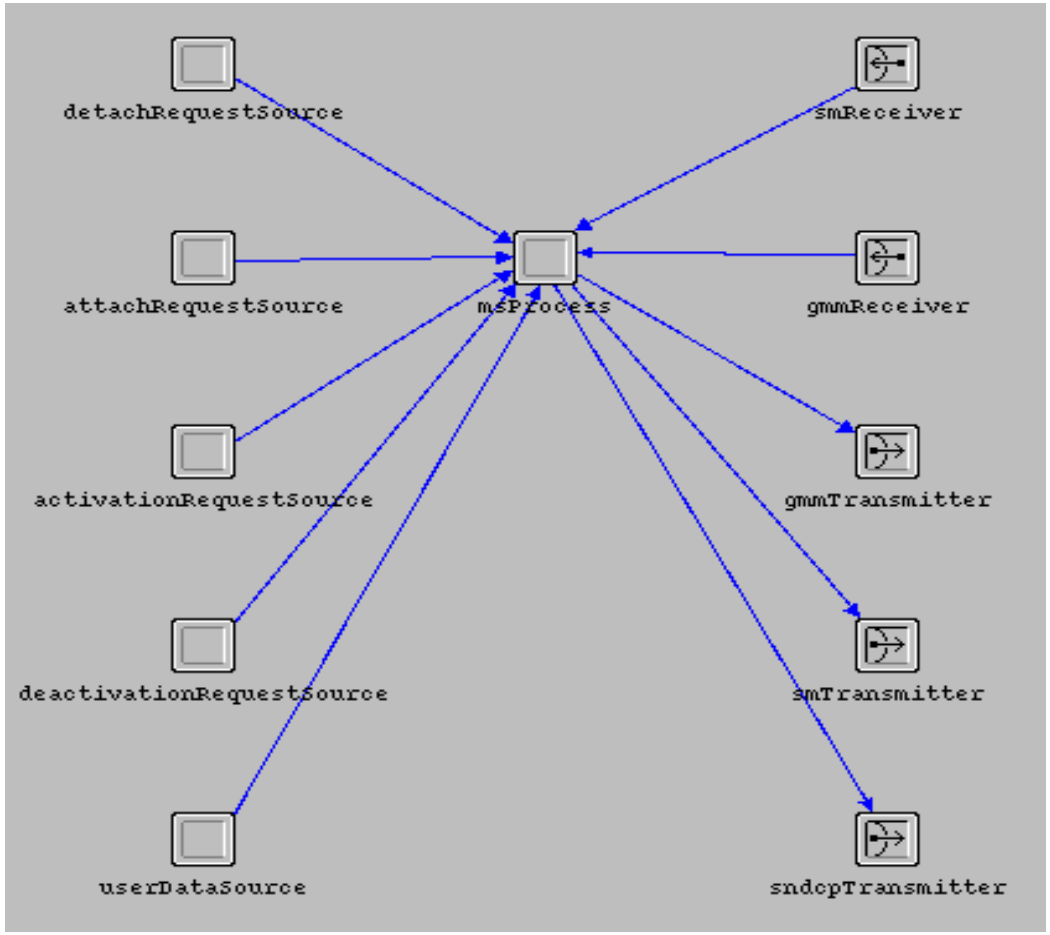
Activation procedure: rejected

Message sequence chart

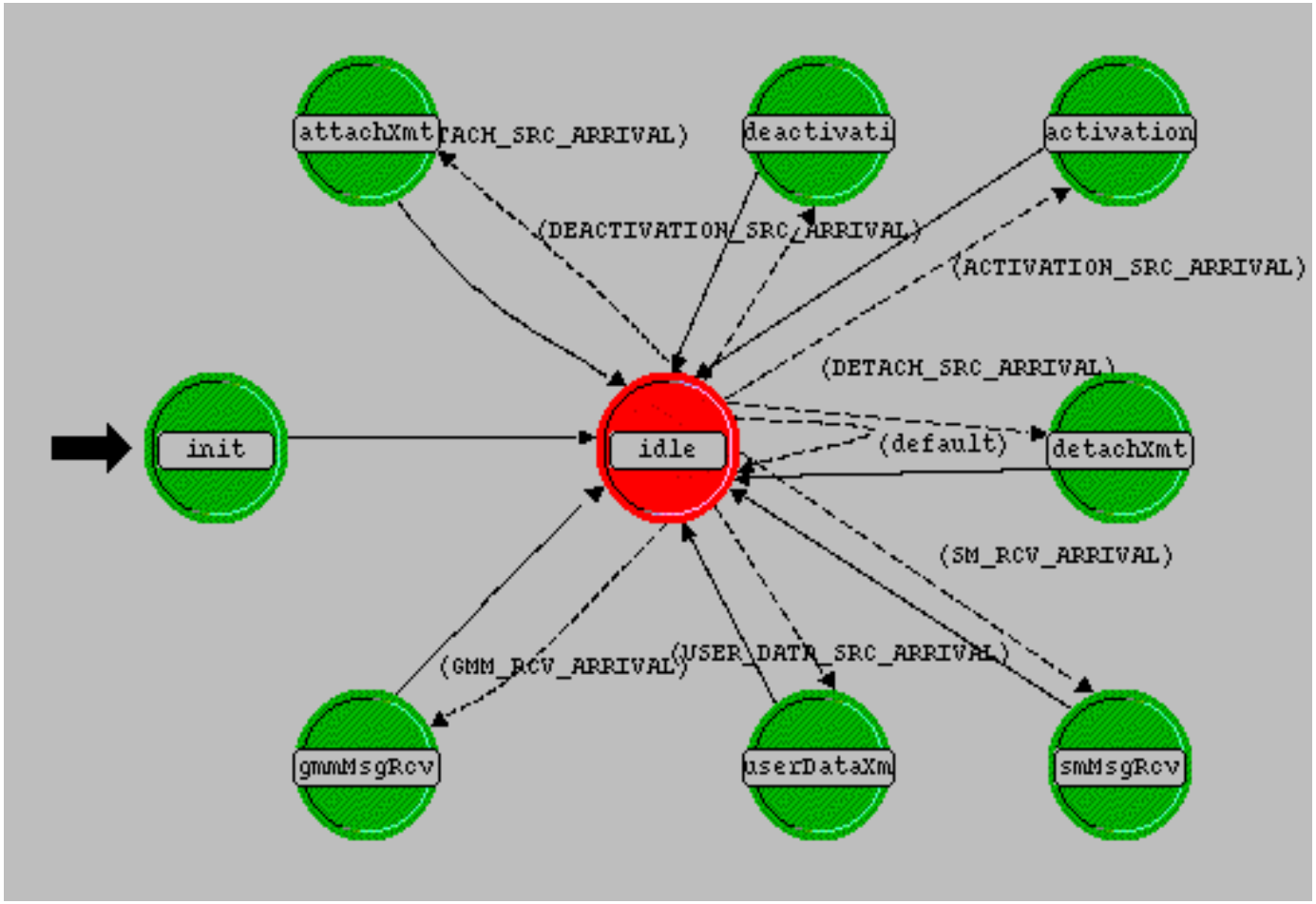


MS: Mobile Station
SGSN: Serving GPRS Support Node
GGSN: Gateway GPRS Support Node
PDP: Packet Data Protocol

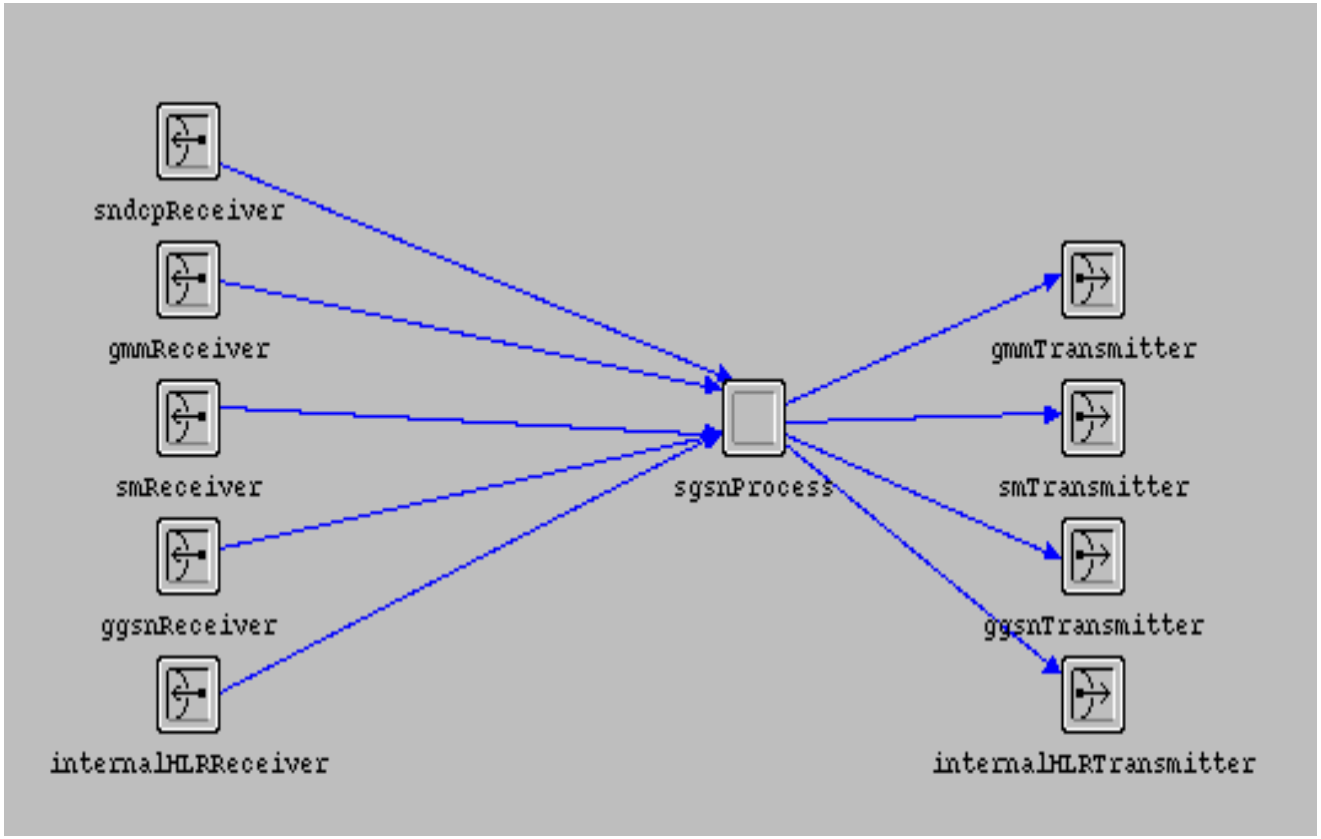
MS node model



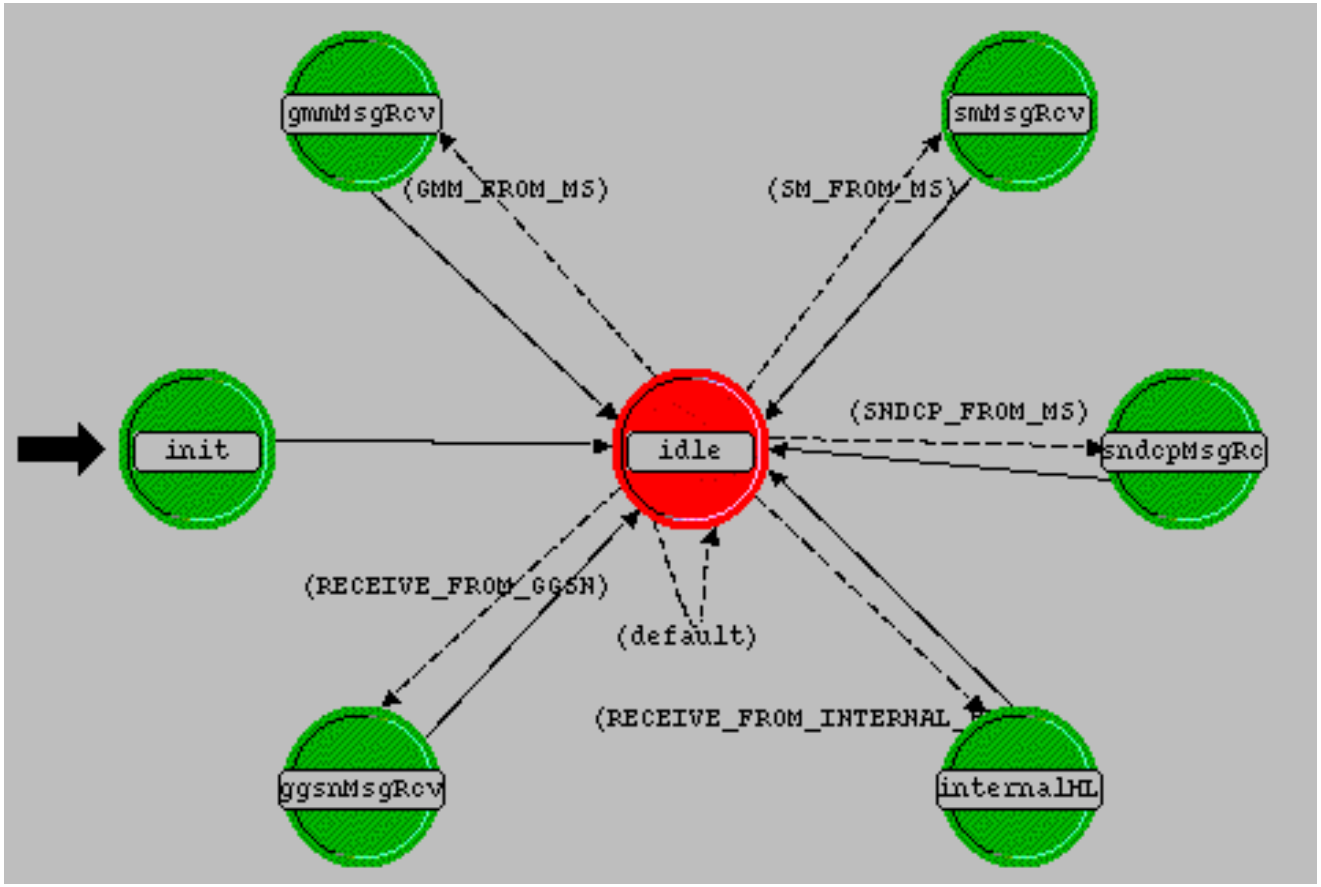
MS process model



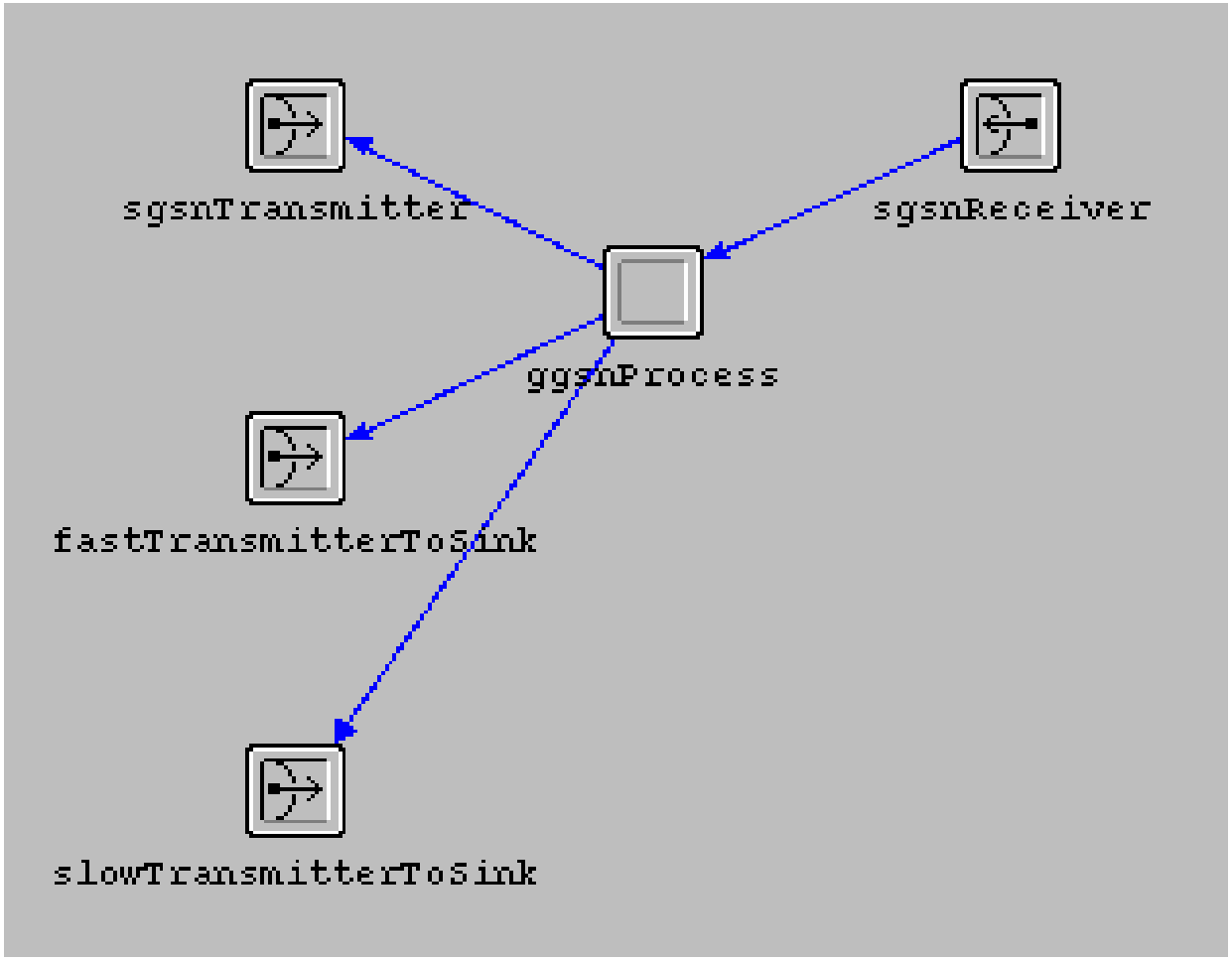
SGSN node model



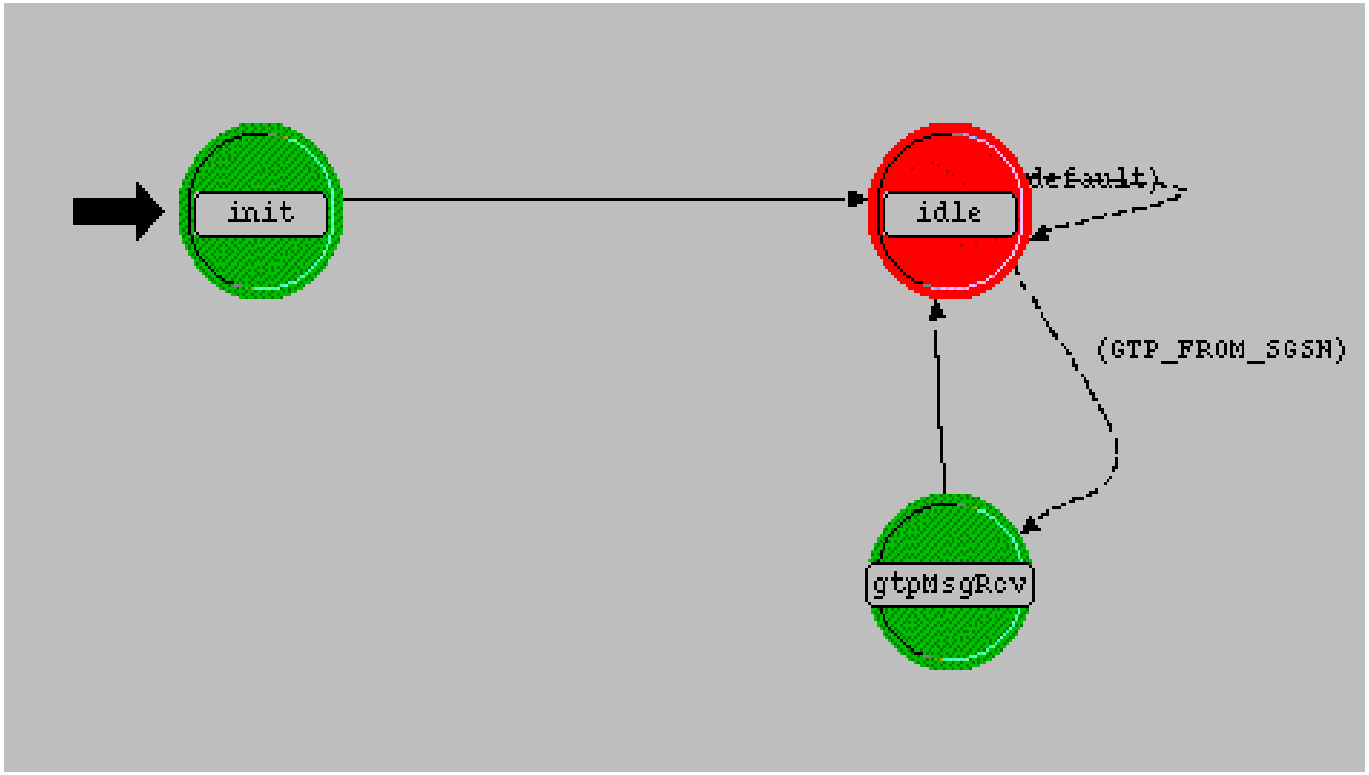
SGSN process model



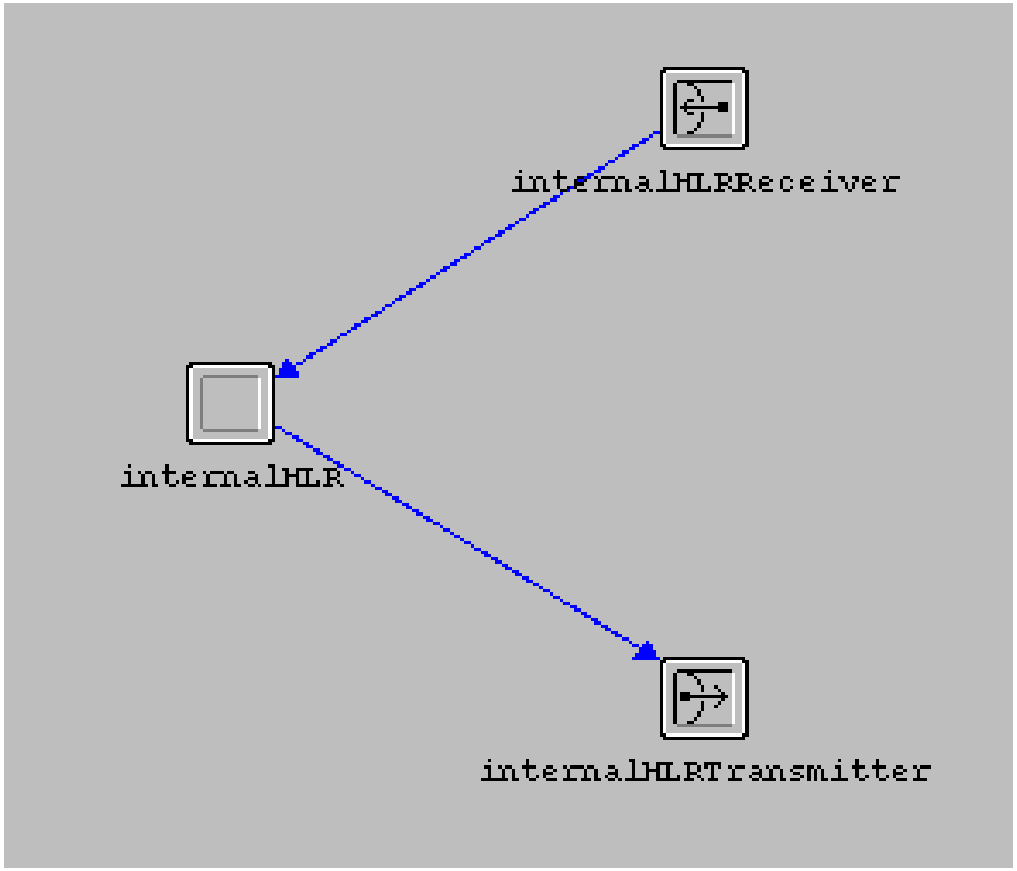
GGSN node model



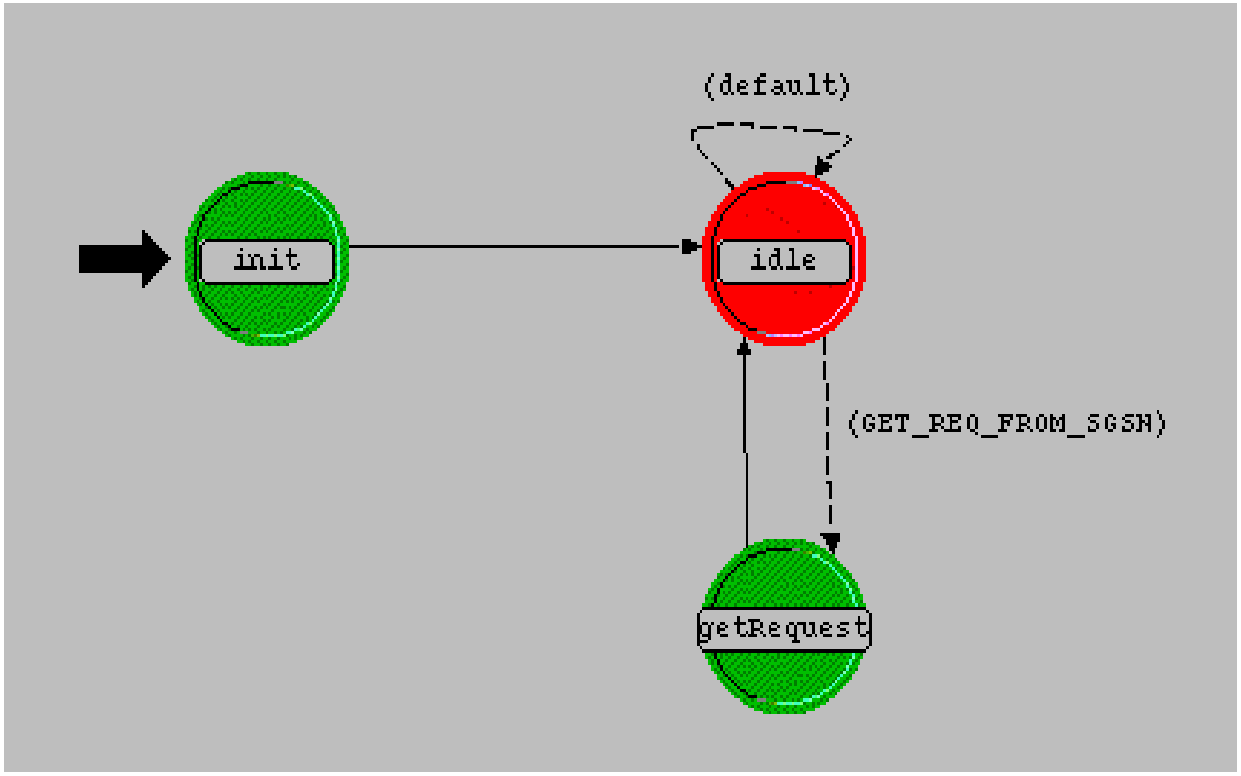
GGSN process model



HLR node model



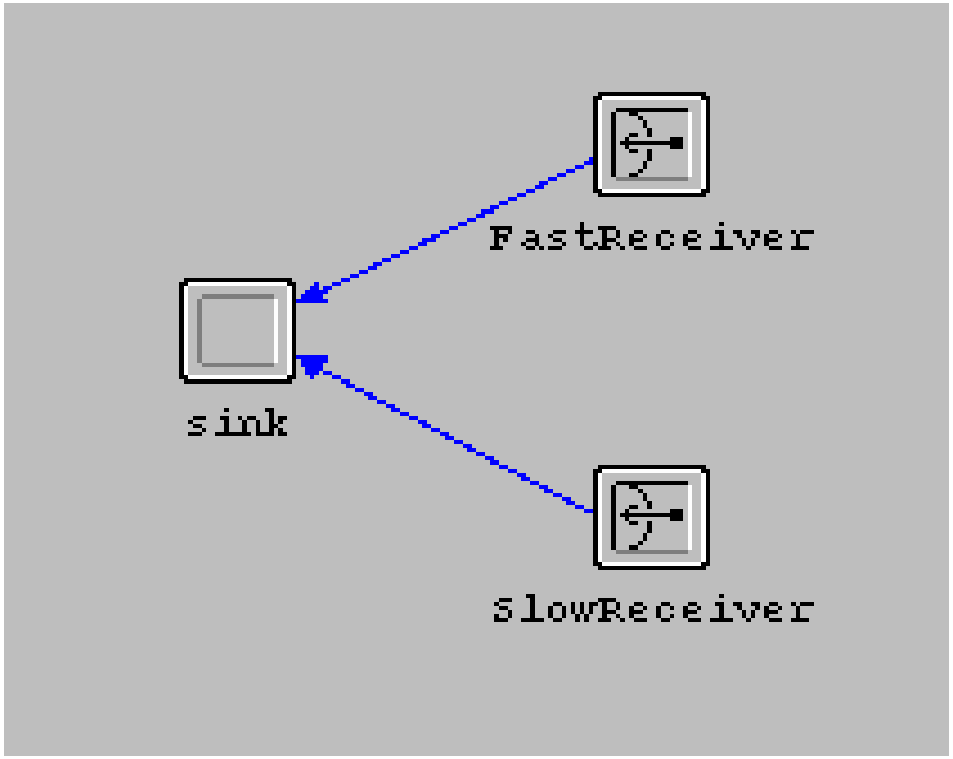
HLR process model



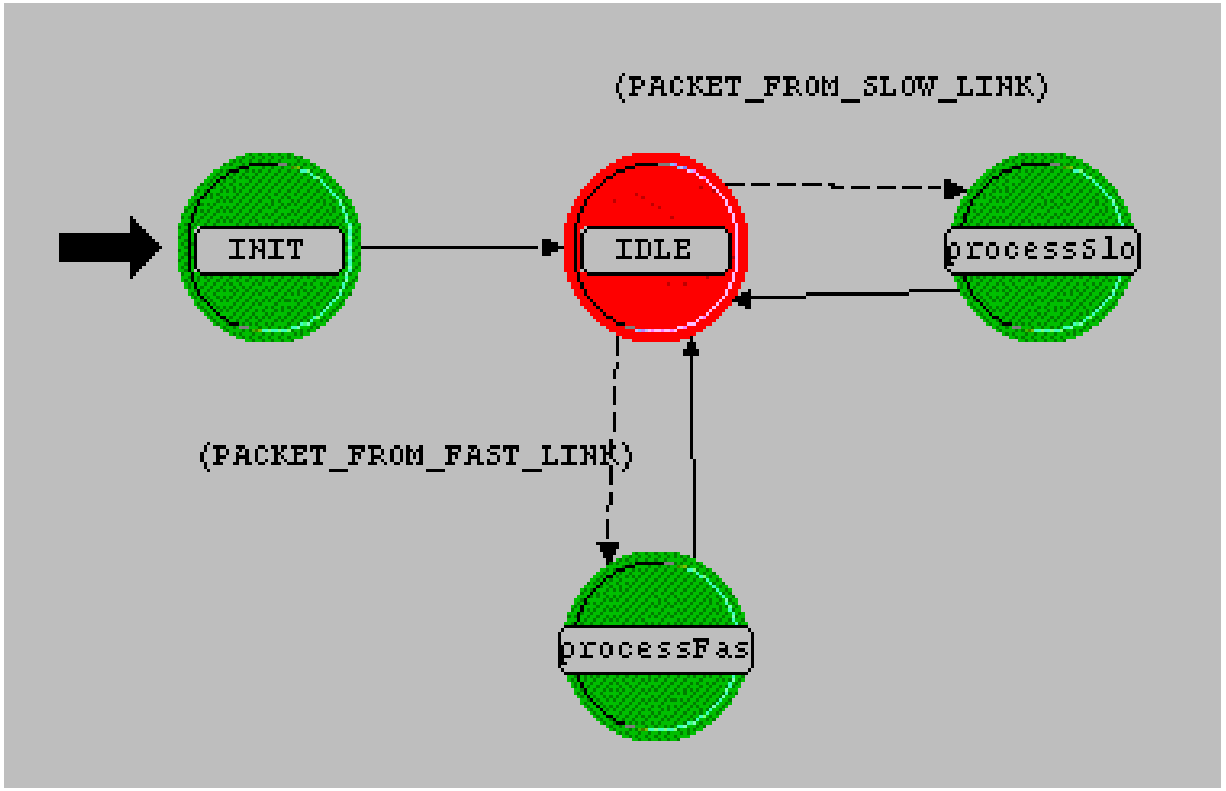
InternalHLR.gdf file

```
# 1st element: International Mobile Subscriber Identity (IMSI)
# 2nd element: Access Point Name (APN)
# 3rd element: Subscribed QoS - reliability class
# 4th element: Subscribed QoS - delay class
# 5th element: Subscribed QoS - precedence class
# 6th element: Subscribed QoS - peak throughput
# 7th element: Subscribed QoS - mean throughput
# 8th element: Packet Data Protocol (PDP) Type
# 9th element: Packet Data Protocol (PDP) Address
0,abc.com,3,4,2,9,8,33,1.2.3.4
1,msn.com,2,3,4,8,7,33,11.12.13.14
2,abc.com,3,4,2,9,8,33,21.22.23.24
3,msn.com,2,3,4,8,7,33,31.32.33.34
4,abc.com,3,4,2,9,8,33,41.42.43.44
5,msn.com,2,3,4,8,7,33,51.52.53.54
6,abc.com,3,4,2,9,8,33,61.62.63.64
7,msn.com,2,3,4,8,7,33,71.72.73.74
8,abc.com,3,4,2,9,8,33,81.82.83.84
9,msn.com,2,3,4,8,7,33,91.92.93.94
10,def.com,3,4,2,9,9,33,101.102.103.104
11,def.com,3,4,2,9,10,33,111.112.113.114
12,def.com,3,4,2,9,10,33,121.122.123.124
```

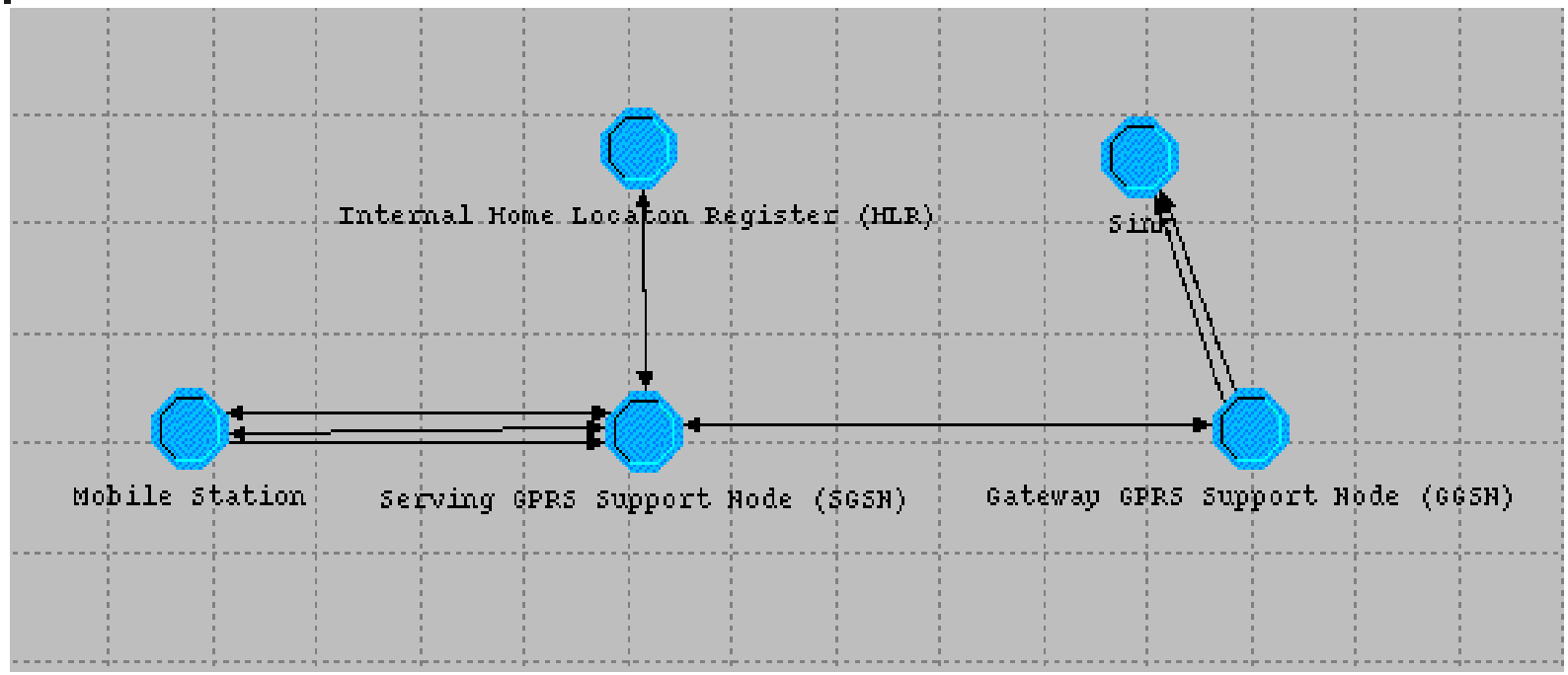
Sink node model



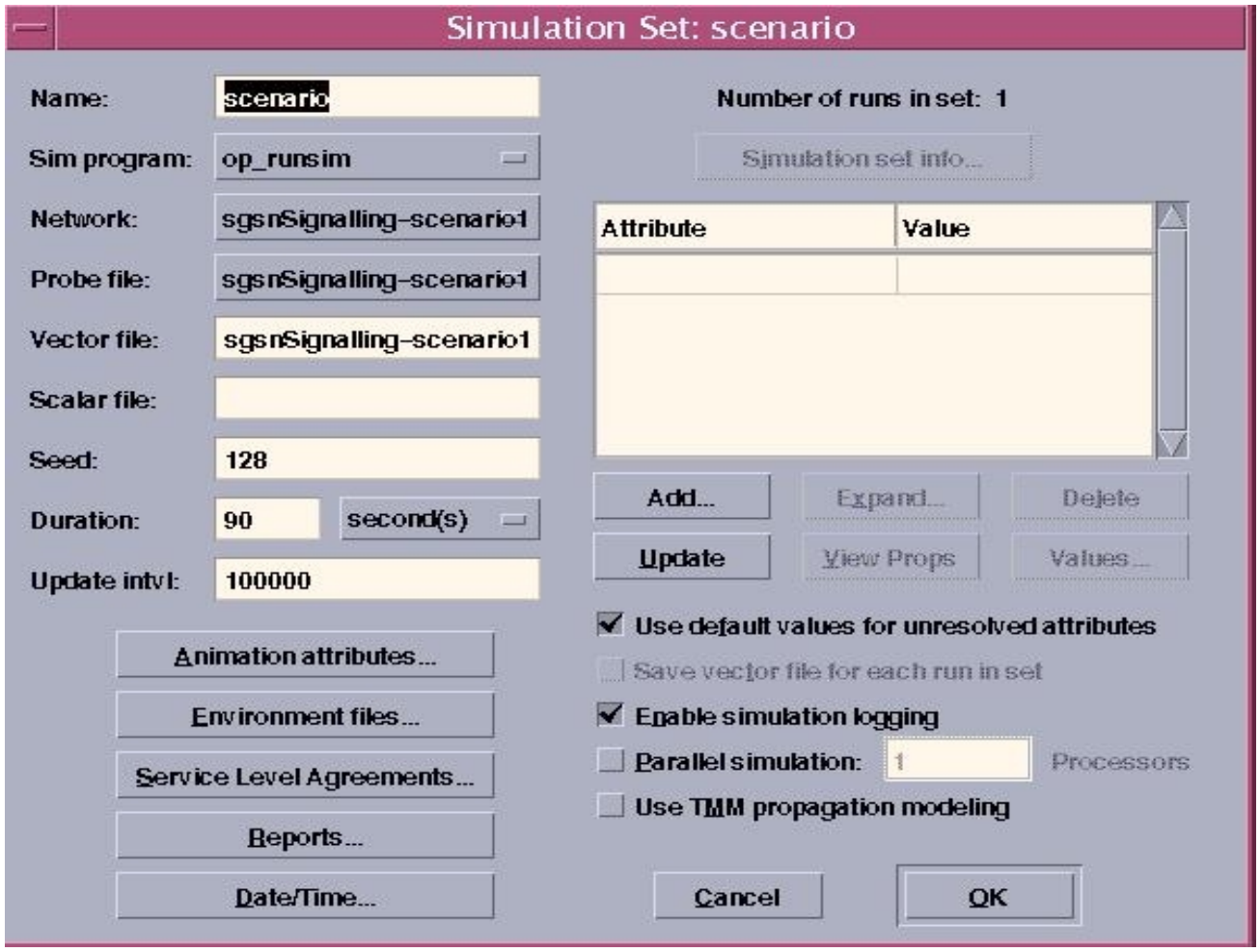
Sink process model



GPRS model project view



Simulation input window



Network configuration

- MS node simulates GPRS users whose MS identifiers range from 0 to 14
- GGSN node supports two (mean) throughput rates:
  - 20,000 octets/hour
  - 10,000 octets/hour
- GGSN node offers two connection speeds to the sink, based on the requested QoS in activation

MS: Mobile Station
GGSN: Gateway GPRS Support Node
QoS: Quality of Service

Network configuration (cont.)

- Internal HLR input file consists of records for MS with identifiers ranging from 0 to 12
- MS with identifiers 10, 11, and 12 have a mean throughput >= 50,000 octets/hour
- MS with even identifiers 0, 2, 4, 6, and 8 have a mean throughput 20,000 octets/hour
- MS with odd identifiers 1, 3, 5, 7, and 9 have a mean throughput 10,000 octets/hour

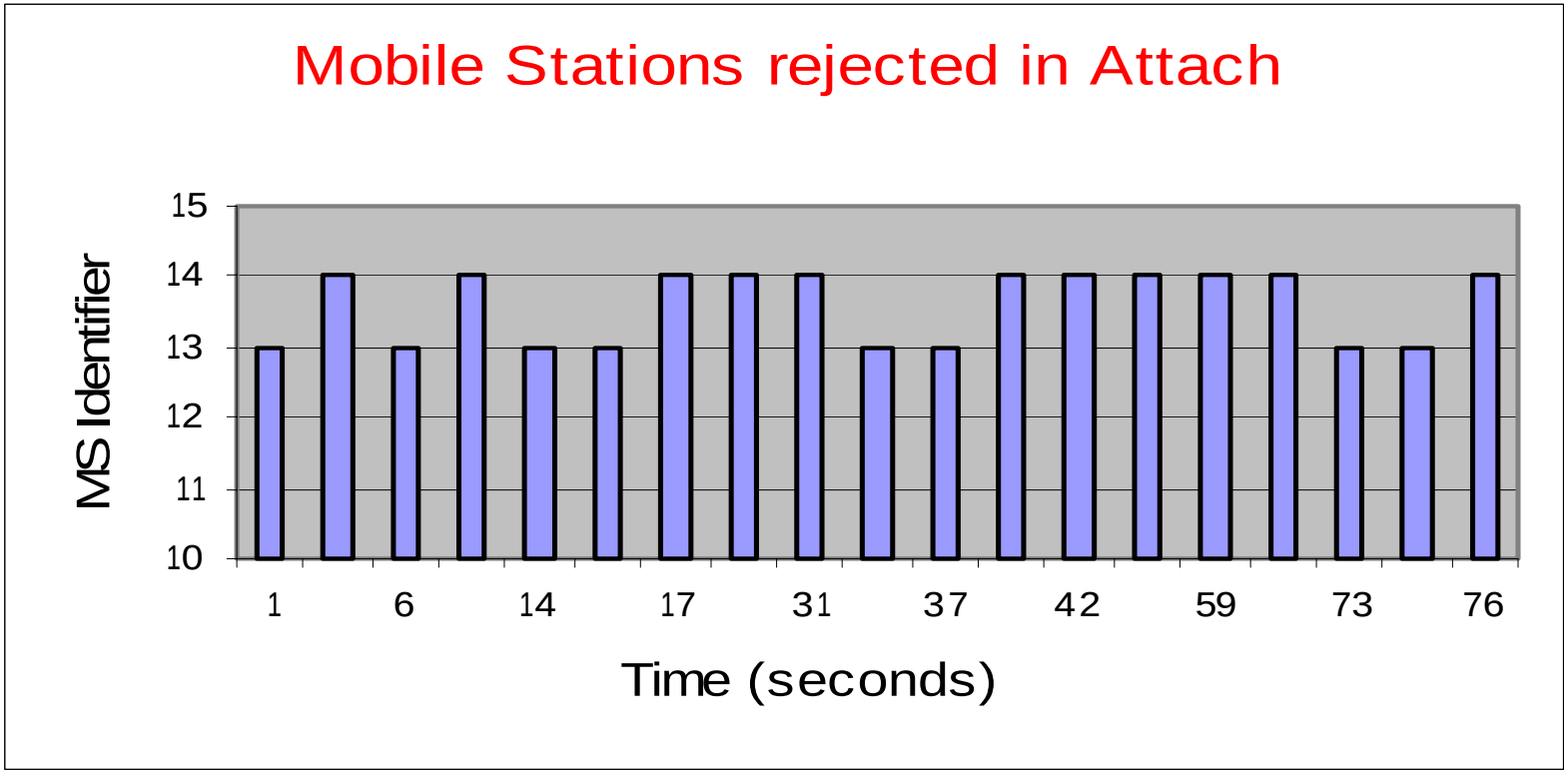
MS: Mobile Station
HLR: Home Location Register

Simulation Scenario 1

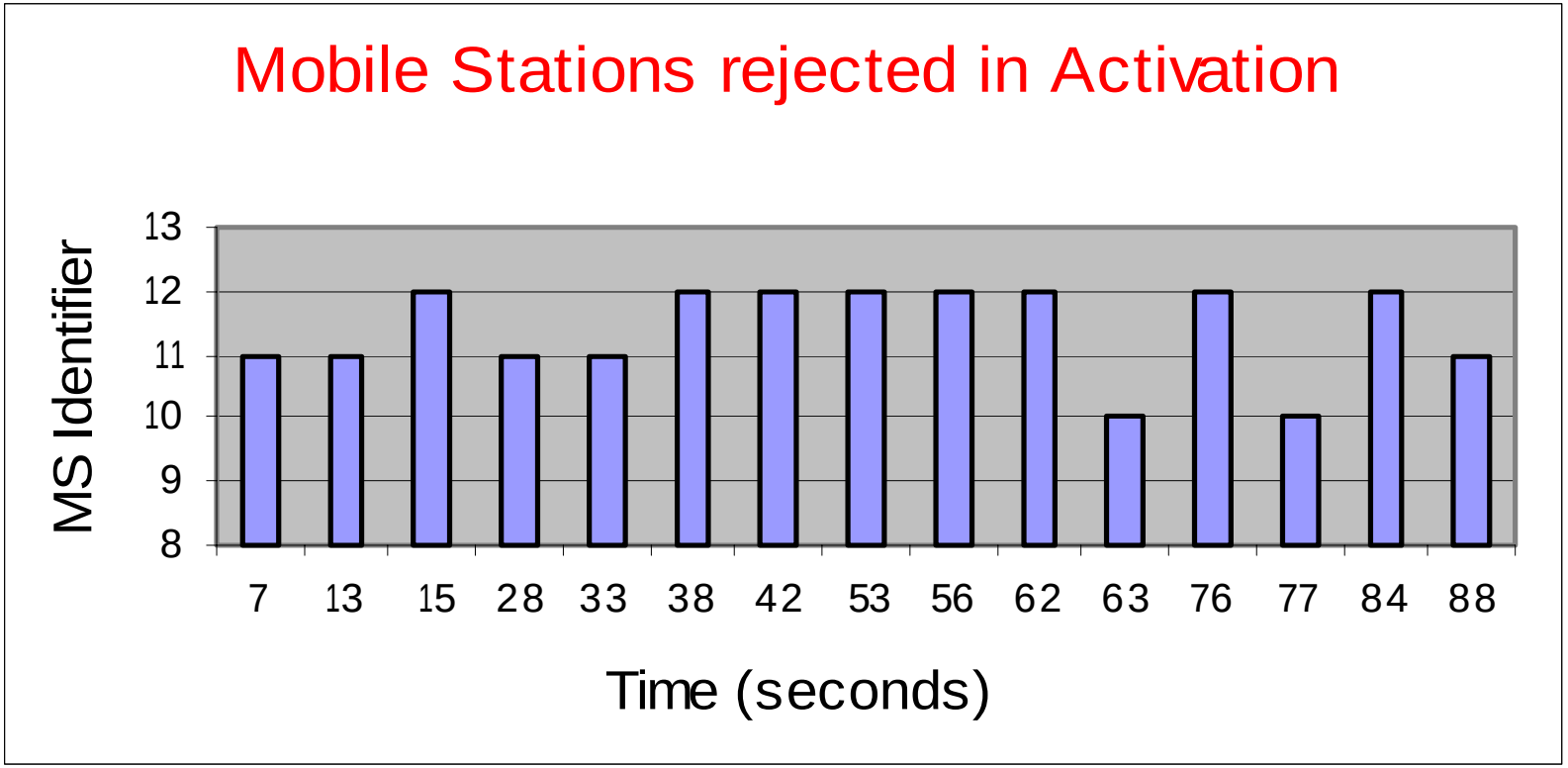
User input attribute	Setting
MS node: Attach Request inter-arrival rate	Constant (mean 0.5)
MS node: Detach Request inter-arrival rate	Constant (mean 2)
MS node: Activation Request inter-arrival rate	Constant (mean 1)
MS node: Deactivation Request inter-arrival rate	Constant (mean 1.5)
MS node: User data inter-arrival rate	Constant (mean 0.5)
Simulation time	15 minutes

MS: Mobile Station

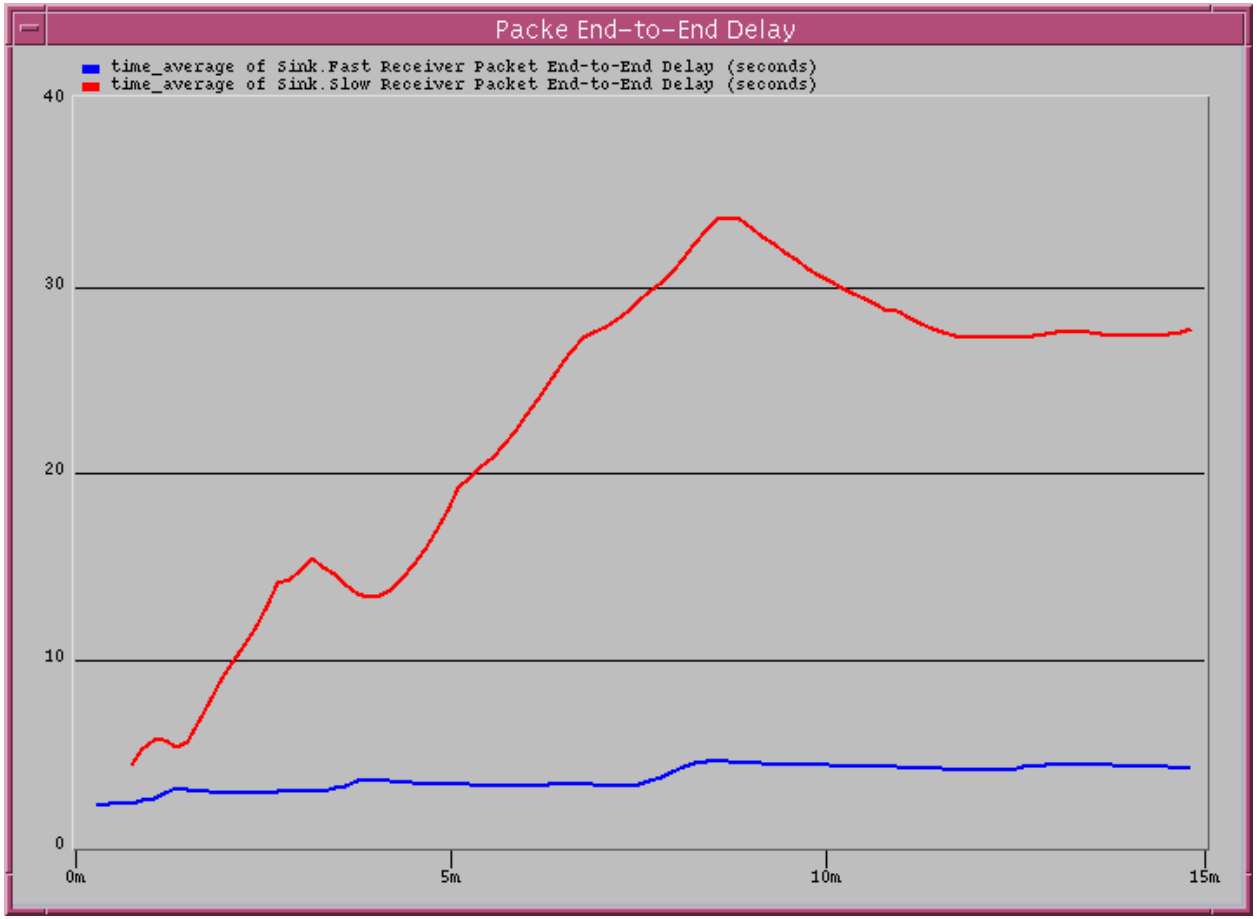
Rejection in Attach



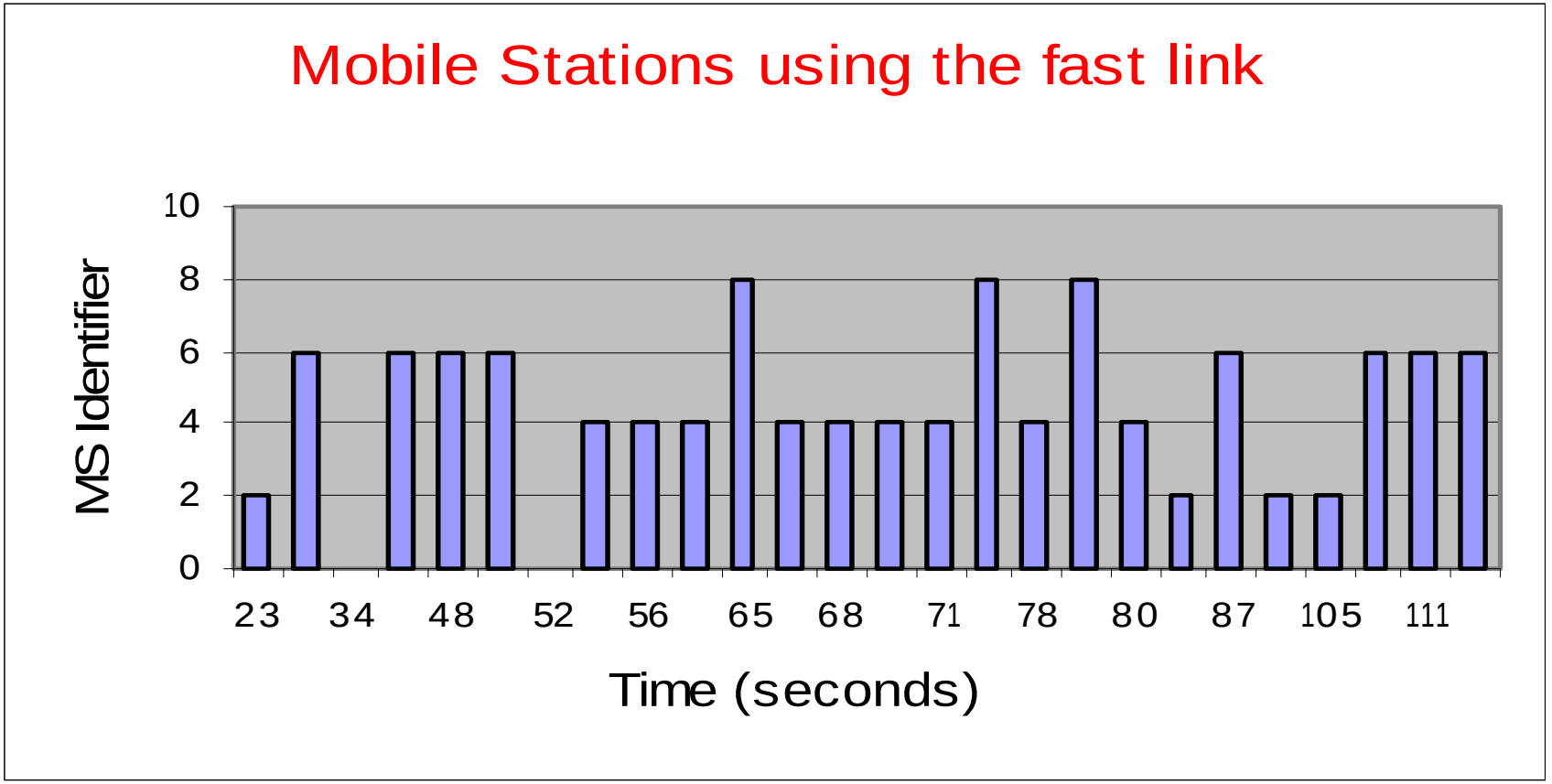
Rejection in Activation



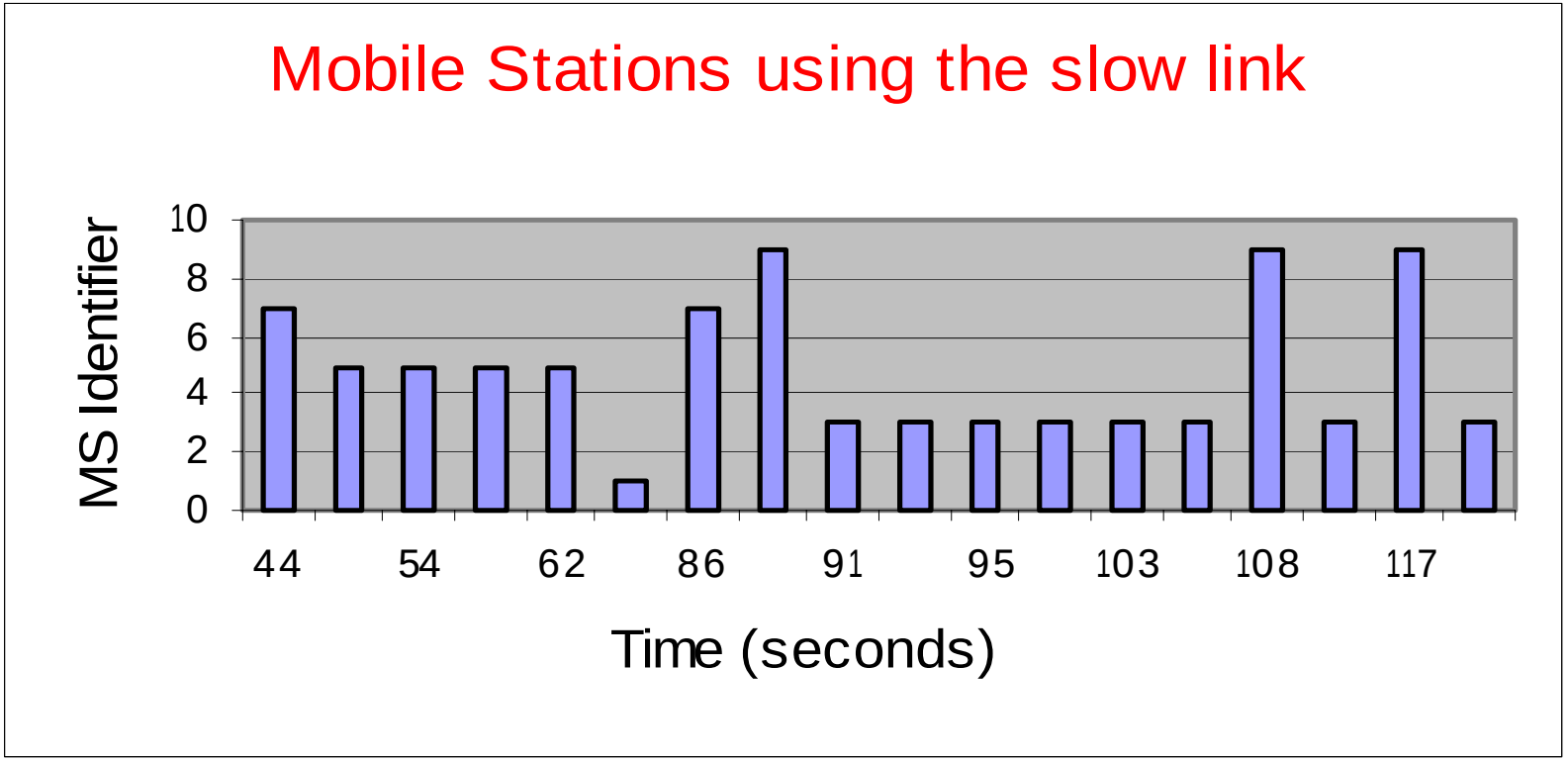
Two classes of QoS: packet end-to-end delays



Two classes of QoS: Mobile Stations using the fast link



Two classes of QoS: Mobile Stations using the slow link



SGSN and MS state information after simulation

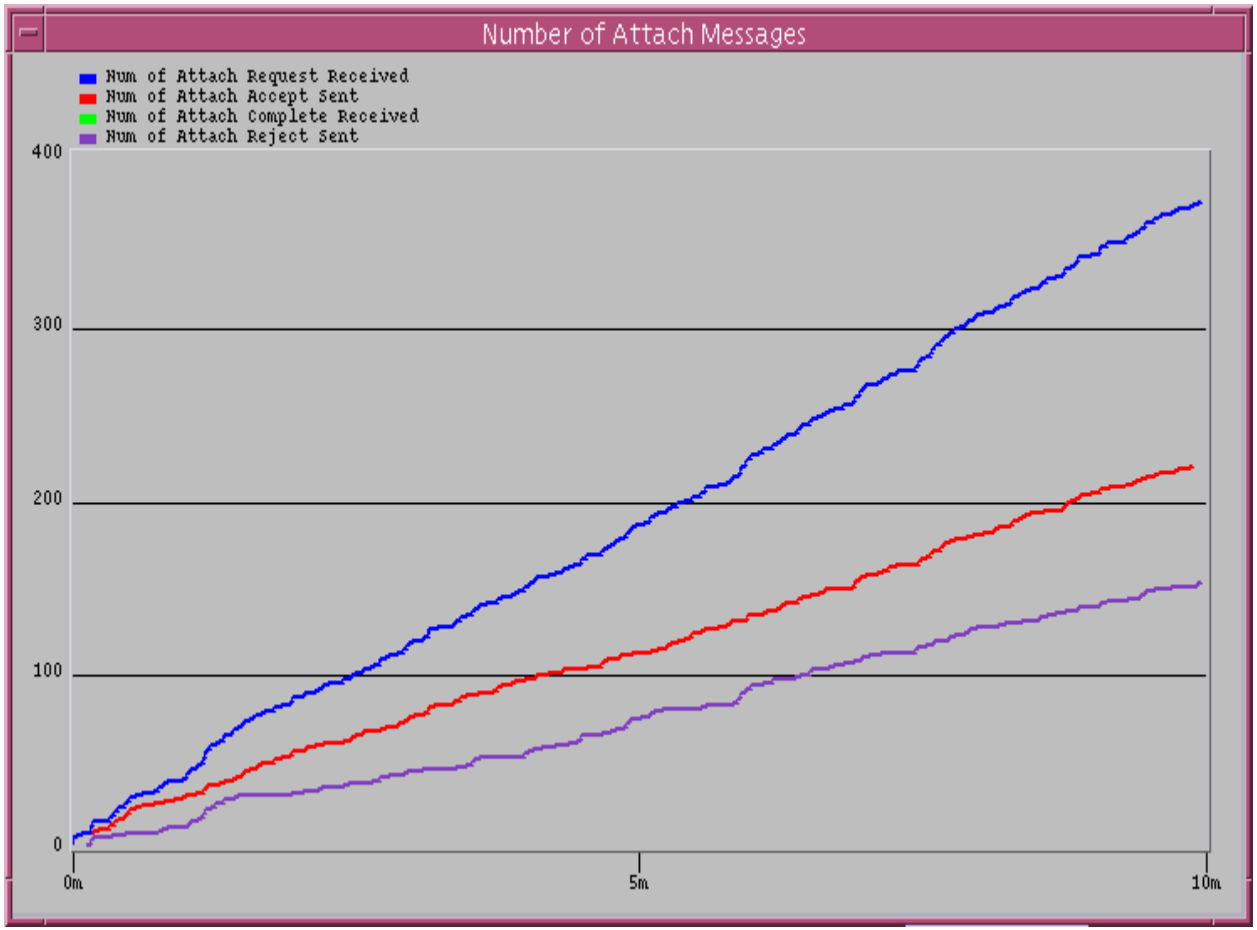
```
SGSN MM and PDP Context after simulation
MM State 0 = detached, 1 = Attached
Attached + Is Active = Activated
----------
IMSI:    0       MM State: 0     Is Active: 0
IMSI:    1       MM State: 1     Is Active: 0
IMSI:    2       MM State: 1     Is Active: 0
IMSI:    3       MM State: 1     Is Active: 1
IMSI:    4       MM State: 1     Is Active: 1
IMSI:    5       MM State: 0     Is Active: 0
IMSI:    6       MM State: 1     Is Active: 0
IMSI:    7       MM State: 1     Is Active: 1
IMSI:    8       MM State: 0     Is Active: 0
IMSI:    9       MM State: 1     Is Active: 1
IMSI:    10      MM State: 0     Is Active: 0
IMSI:    11      MM State: 1     Is Active: 0
IMSI:    12      MM State: 1     Is Active: 0
State information of MS after simulation, 0 = Detached, 1 = Attached, 2 = Activated
IMSI:    0       MM State: 0
IMSI:    1       MM State: 1
IMSI:    2       MM State: 1
IMSI:    3       MM State: 2
IMSI:    4       MM State: 2
IMSI:    5       MM State: 0
IMSI:    6       MM State: 1
IMSI:    7       MM State: 2
IMSI:    8       MM State: 0
IMSI:    9       MM State: 2
IMSI:    10      MM State: 0
IMSI:    11      MM State: 1
IMSI:    12      MM State: 1
```

Simulation Scenario 2

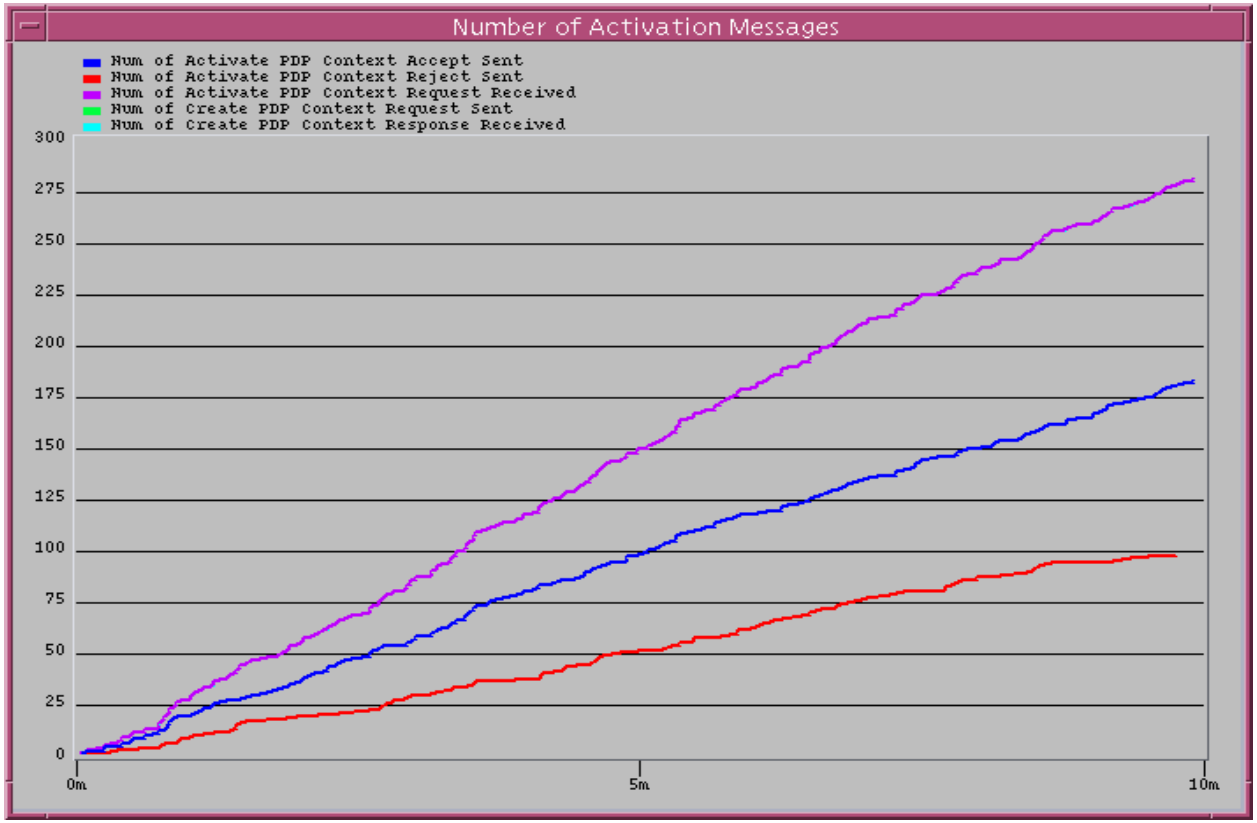
User Input Attribute	Setting
MS node: Attach Request inter-arrival rate	Exponential (mean 0.5)
MS node: Detach Request inter-arrival rate	Exponential (mean 2)
MS node: Activation Request inter-arrival rate	Exponential (mean 1)
MS node: Deactivation Request inter-arrival rate	Exponential (mean 1.5)
MS node: User data inter-arrival rate	Exponential (mean 0.5)
Simulation time	10 minutes

MS: Mobile Station

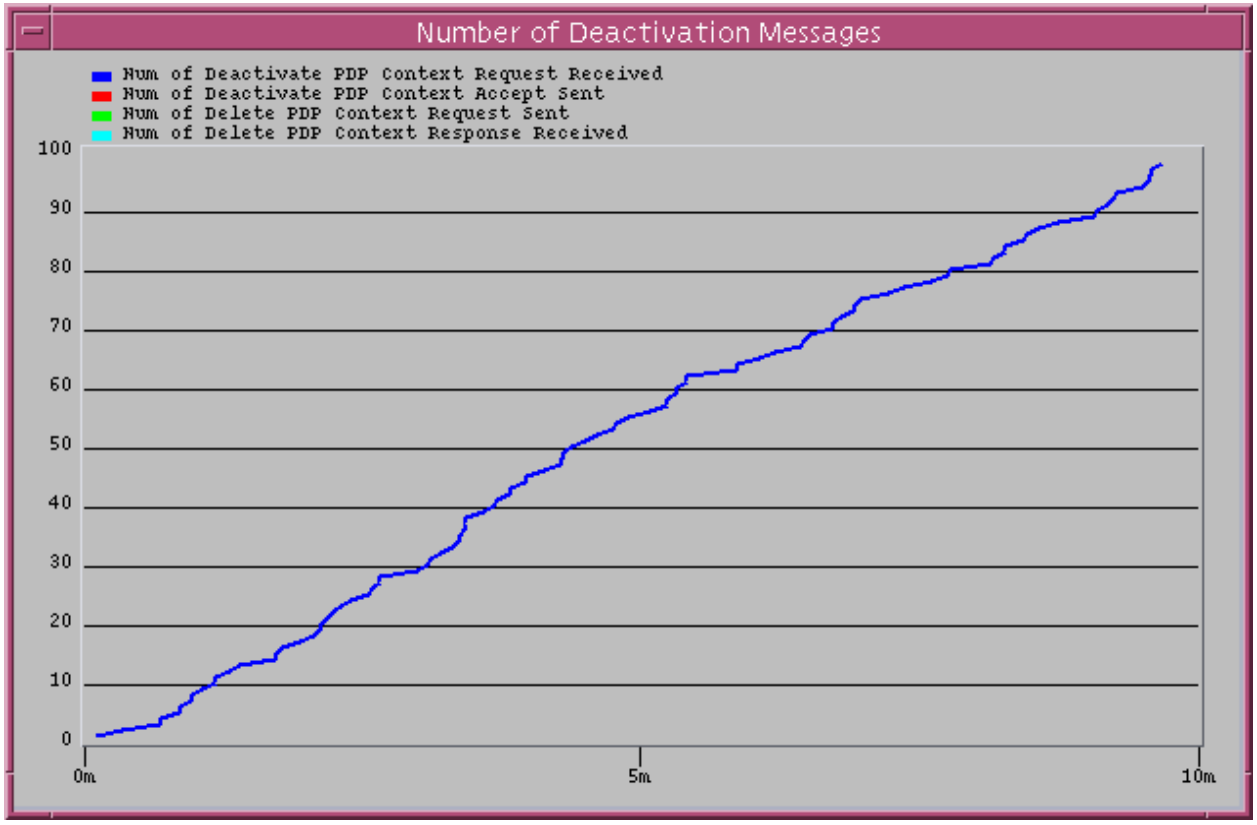
Number of Attach messages



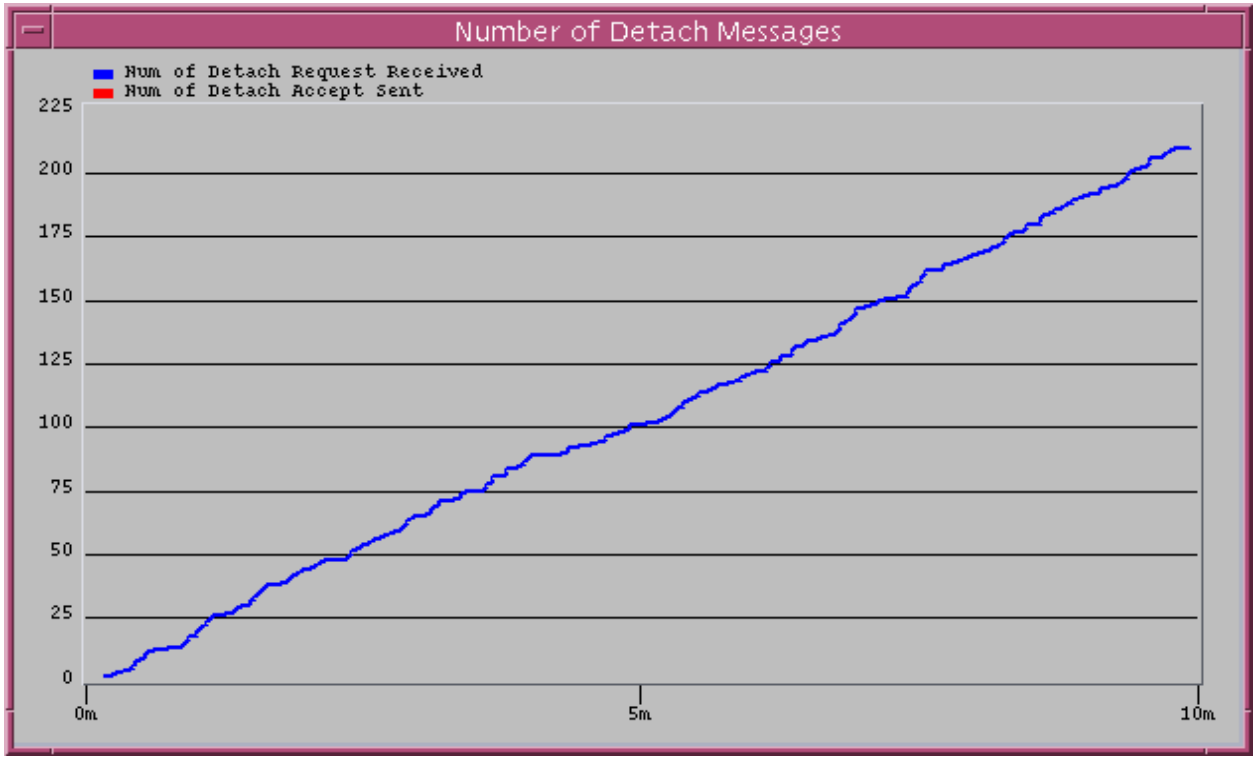
Number of Activation messages



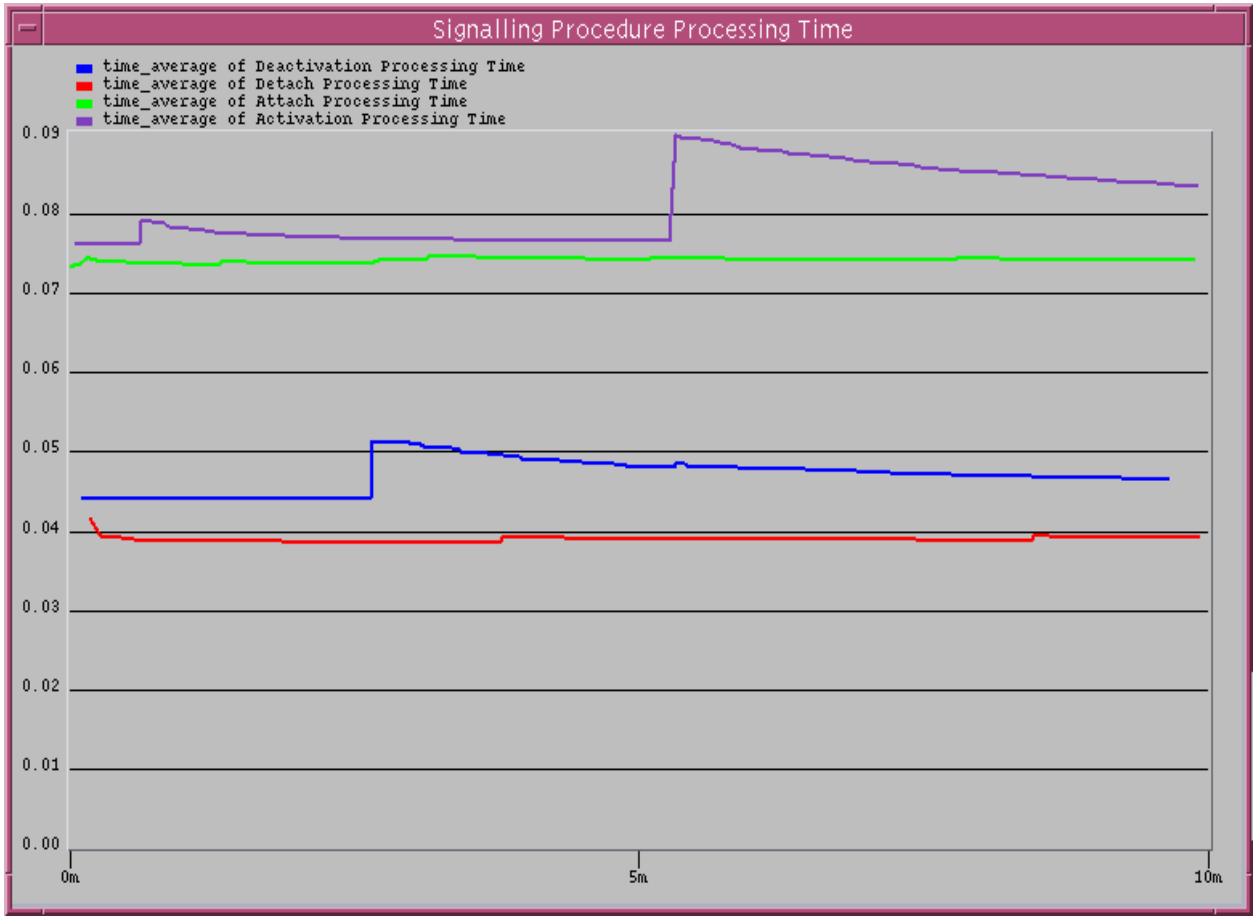
Number of Deactivation messages



Number of Detach messages



Signaling procedures processing time



Improvements

- Use genuine network data to model GPRS network components to identify bottlenecks
- Use genuine traffic data and trace-driven OPNET simulations to evaluate performance
- Platform for prototyping: prove of concept
- Evaluate performance impact due to new service features

Conclusions

- GPRS addresses the growing demand for faster data transmission for mobile stations
- To deploy GPRS, existing GSM network operation requires two new network nodes:
  - SGSN and
  - GGSN

GSM: Global System for Mobile communication
SGSN: Serving GPRS Support Node
GGSN: Gateway GPRS Support Node

Conclusions (cont.)

- OPNET implementation of a GPRS network includes:
  - node model: interface
  - packet format: protocol
  - process model: behavior
  - project window: simulation

Conclusions (cont.)

- It models basic GPRS procedures:
  - attach and activation
  - user data transmission
  - detach and deactivation
- Simulation scenarios demonstrate:
  - implementation of basic GPRS procedures
  - two classes of QoS in data transmission
  - capability of collecting network performance data
- Improvements:
  - incorporate genuine traffic data to identify bottlenecks and measure network performance

References

- OPNET Technology Inc., Washington DC, OPNET documentation, v8.0.
- 3rd Generation Partnership Project, GSM 03.60 v6.8.0, General Packet Radio Service (GPRS), Service Description.
- R. J. Bates, *GPRS: General Packet Radio Service.* New York: McGraw-Hill, 2001.
- H. Granbohm and J. Wiklund, "GPRS-general packet radio service," *Ericsson Review*, no. 2, 1999, pp. 82-88.