



Simulation of General Packet Radio Service Network

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Credits

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

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Road map

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



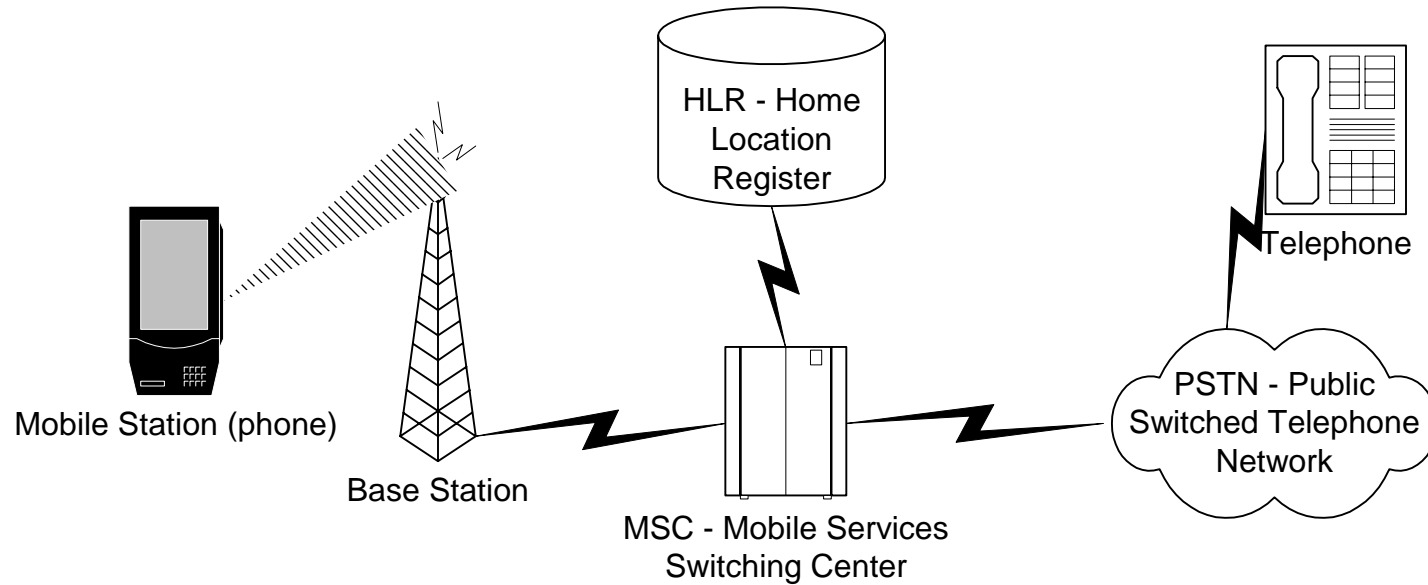
What is GSM?

- Stands for **G**lobal **S**ystem for **M**obile 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





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



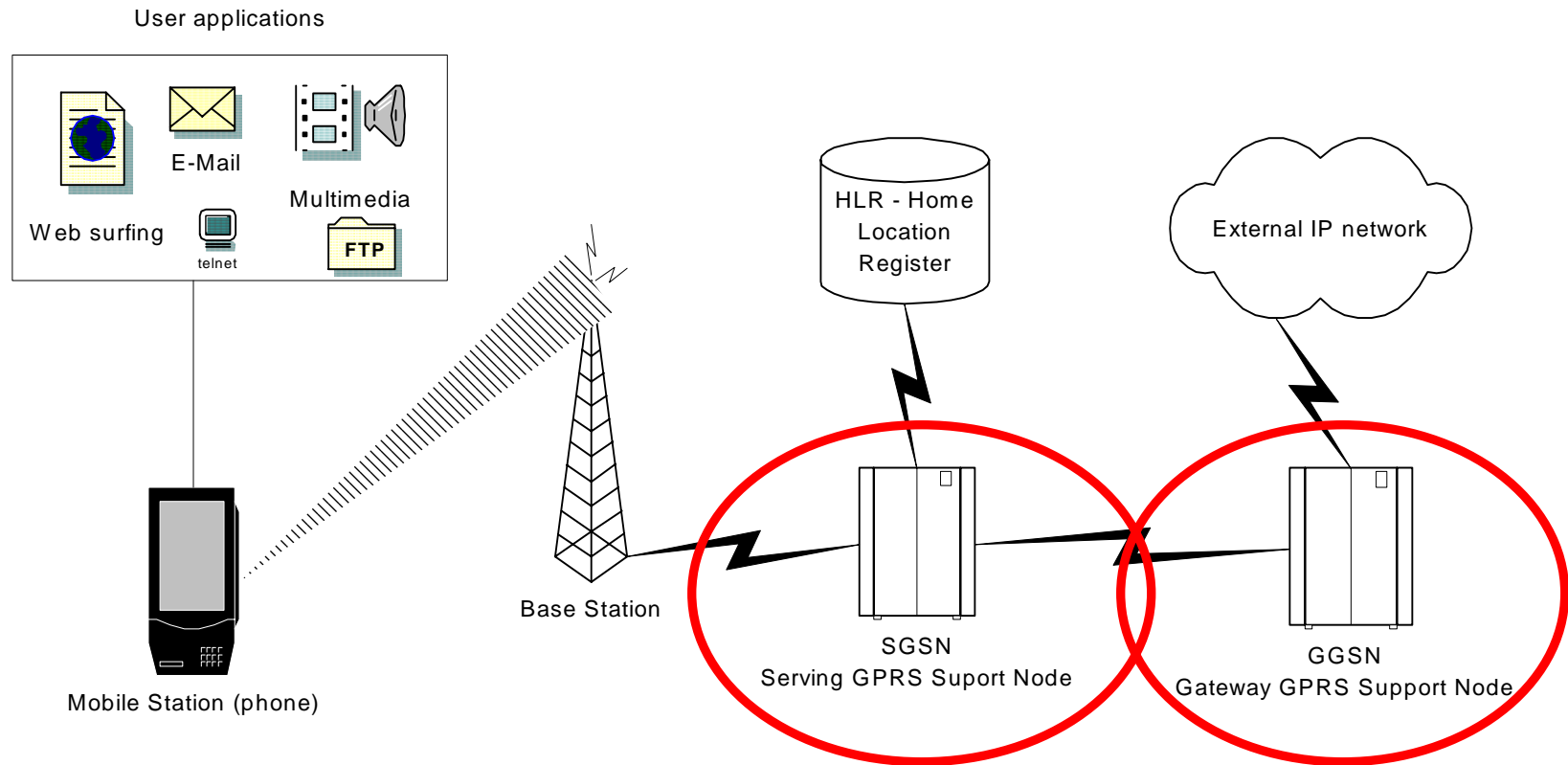
Solution: GPRS

- 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

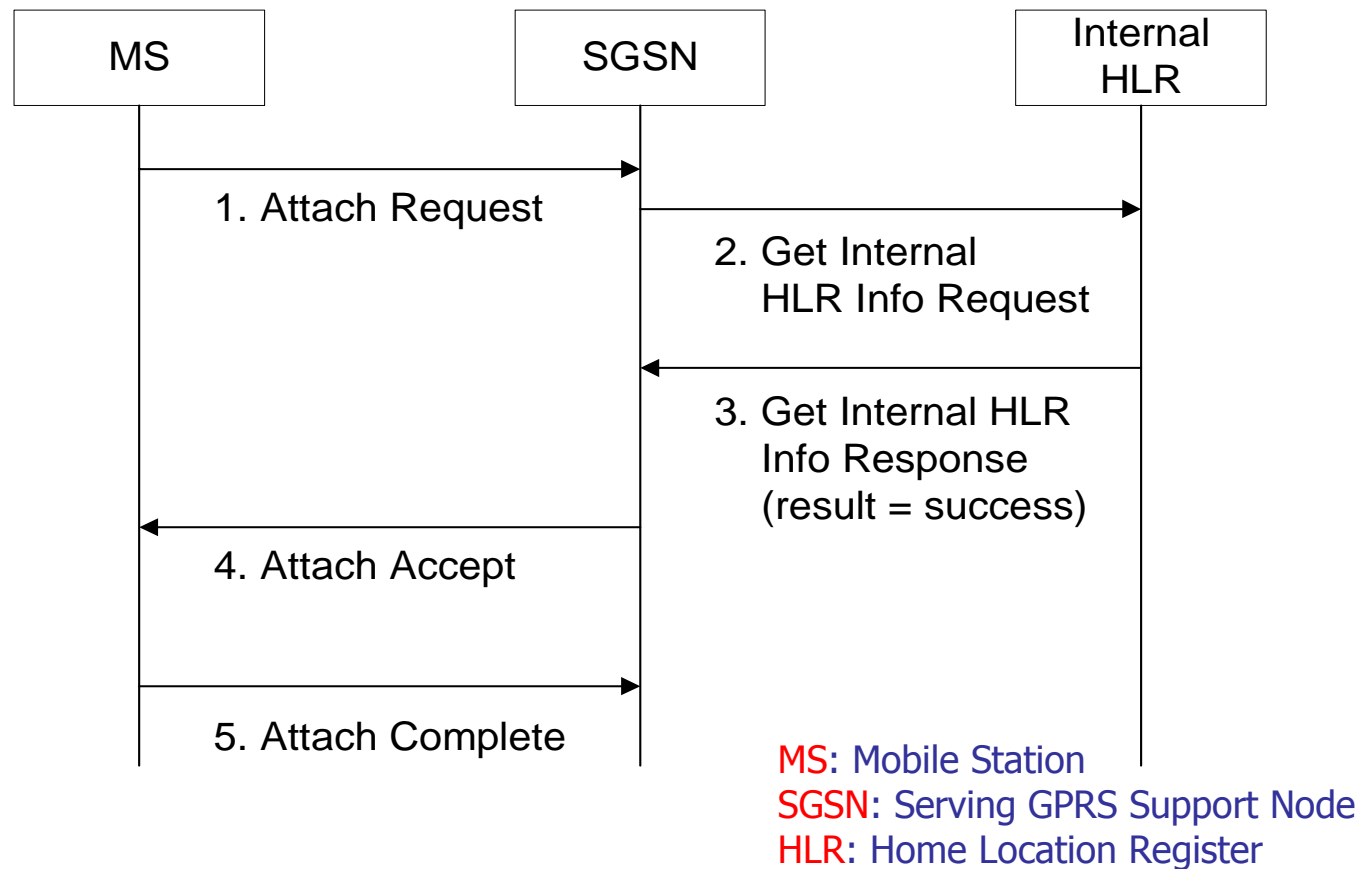
- MS makes itself known to the GPRS network via **Attach**
- Once the MS is attached to the network, the network knows the location and capabilities of the MS

MS: Mobile Station



Attach procedure: accepted

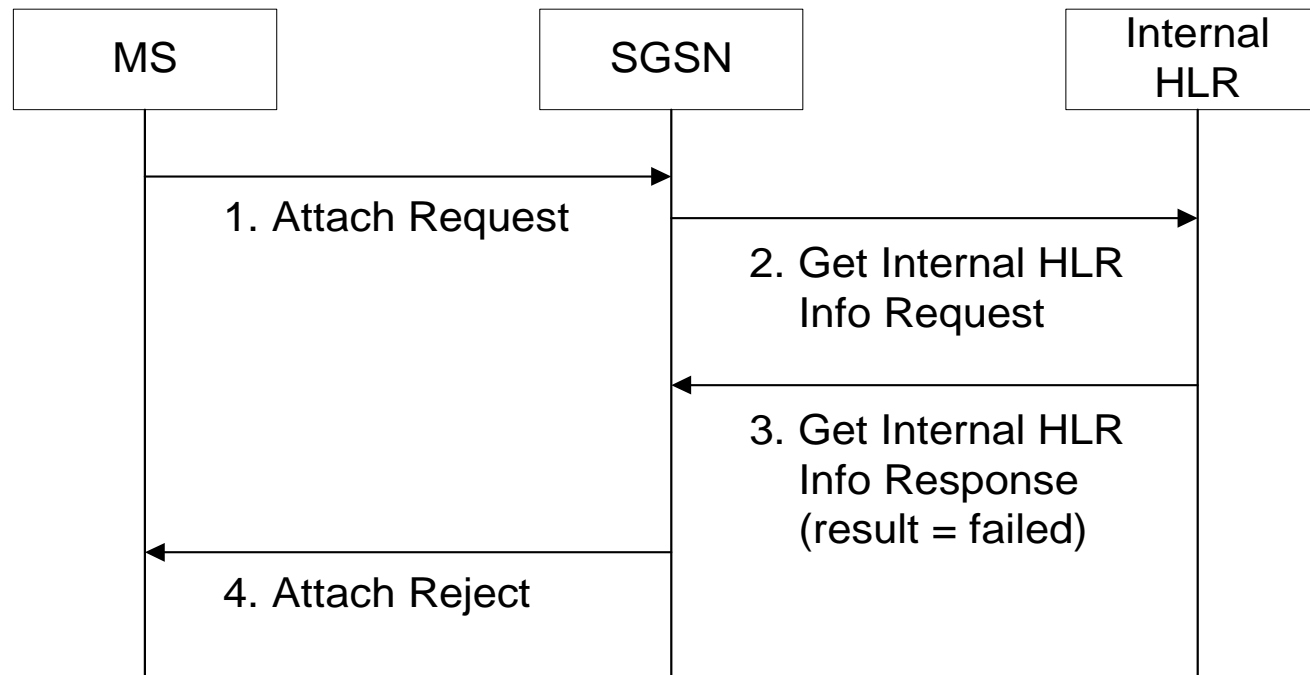
Message sequence chart





Attach procedure: rejected

Message sequence chart



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



Activation procedure

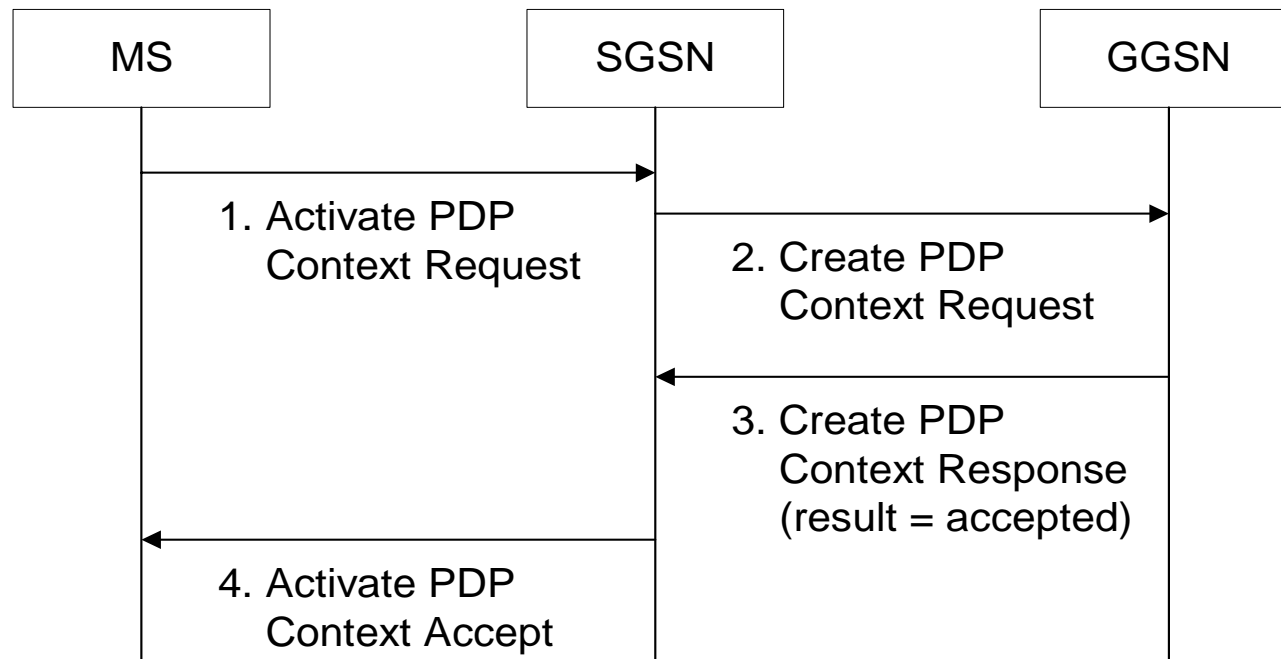
- Before MS can communicate with sink, the **P**acket **D**ata **P**rotocol (PDP) context must be activated
- PDP context describes the characteristics of the connection to the sink:
 - requested QoS
 - data session identifier
 - type of external network to which it is connected
- MS can start sending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

MS: Mobile Station
QoS: Quality of Service



Activation procedure: accepted

Message sequence chart

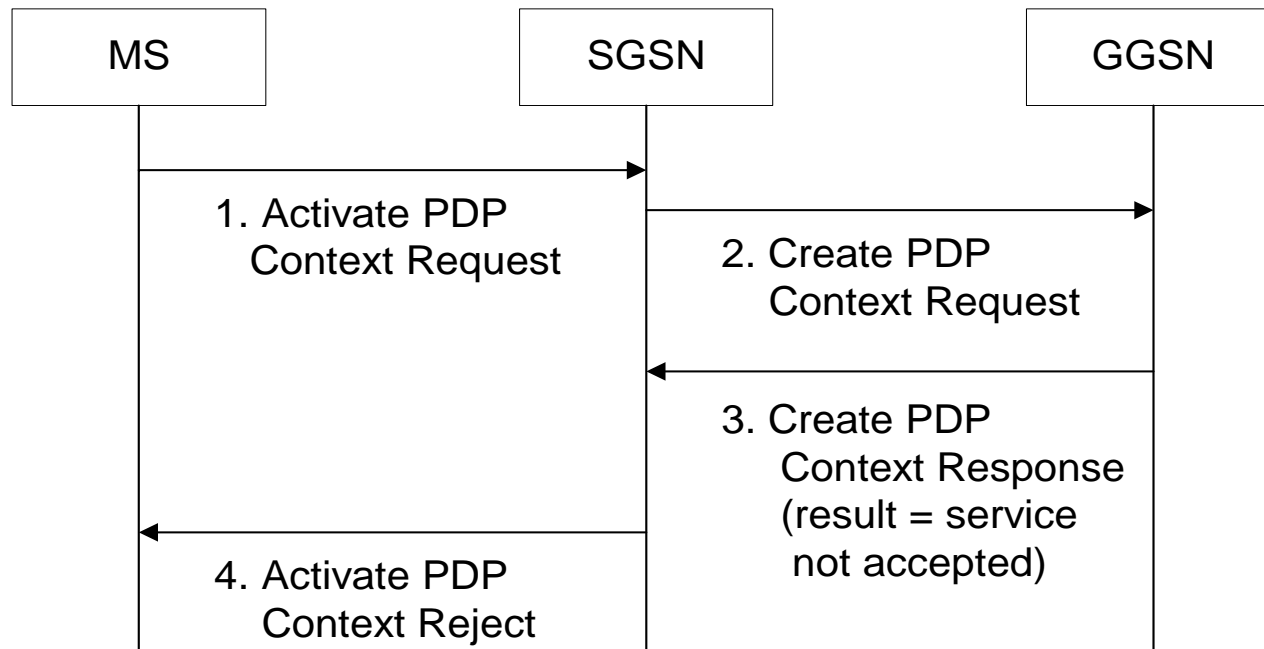


MS: Mobile Station
SGSN: Serving GPRS Support Node
GGSN: Gateway GPRS Support Node
PDP: Packet Data Protocol



Activation procedure: rejected

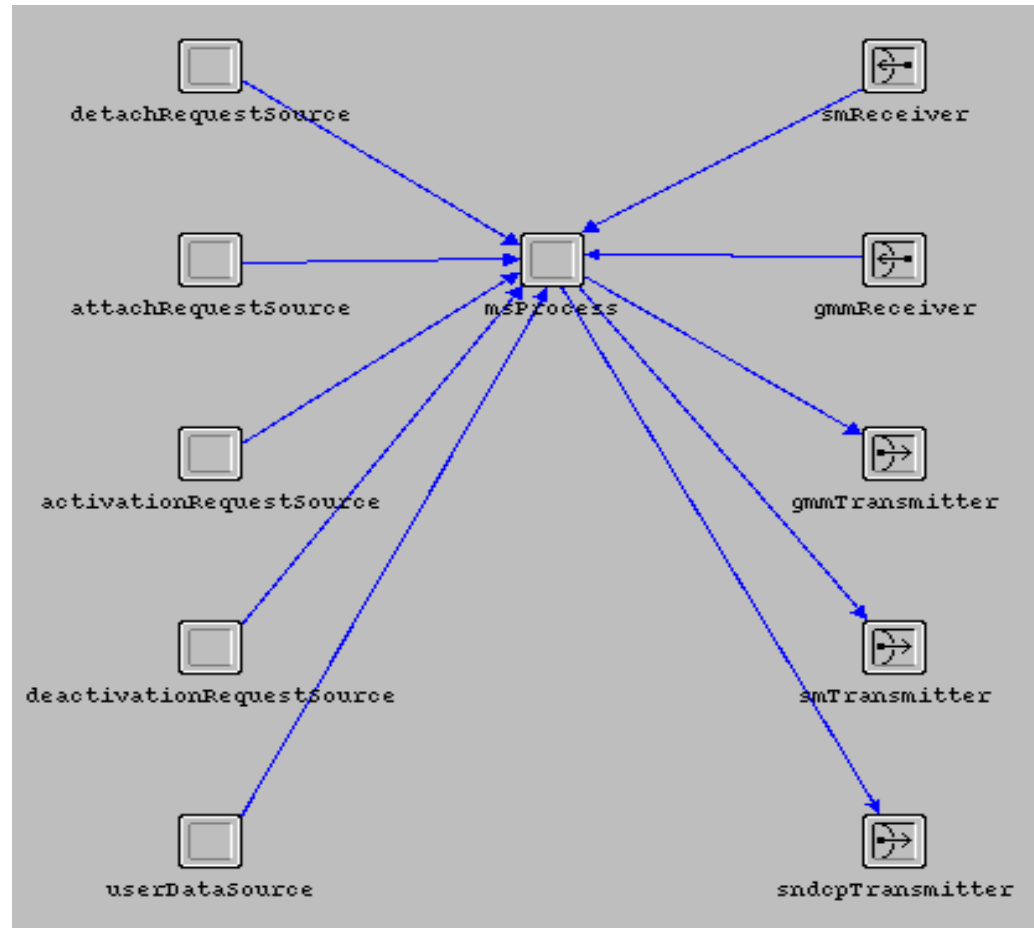
Message sequence chart



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

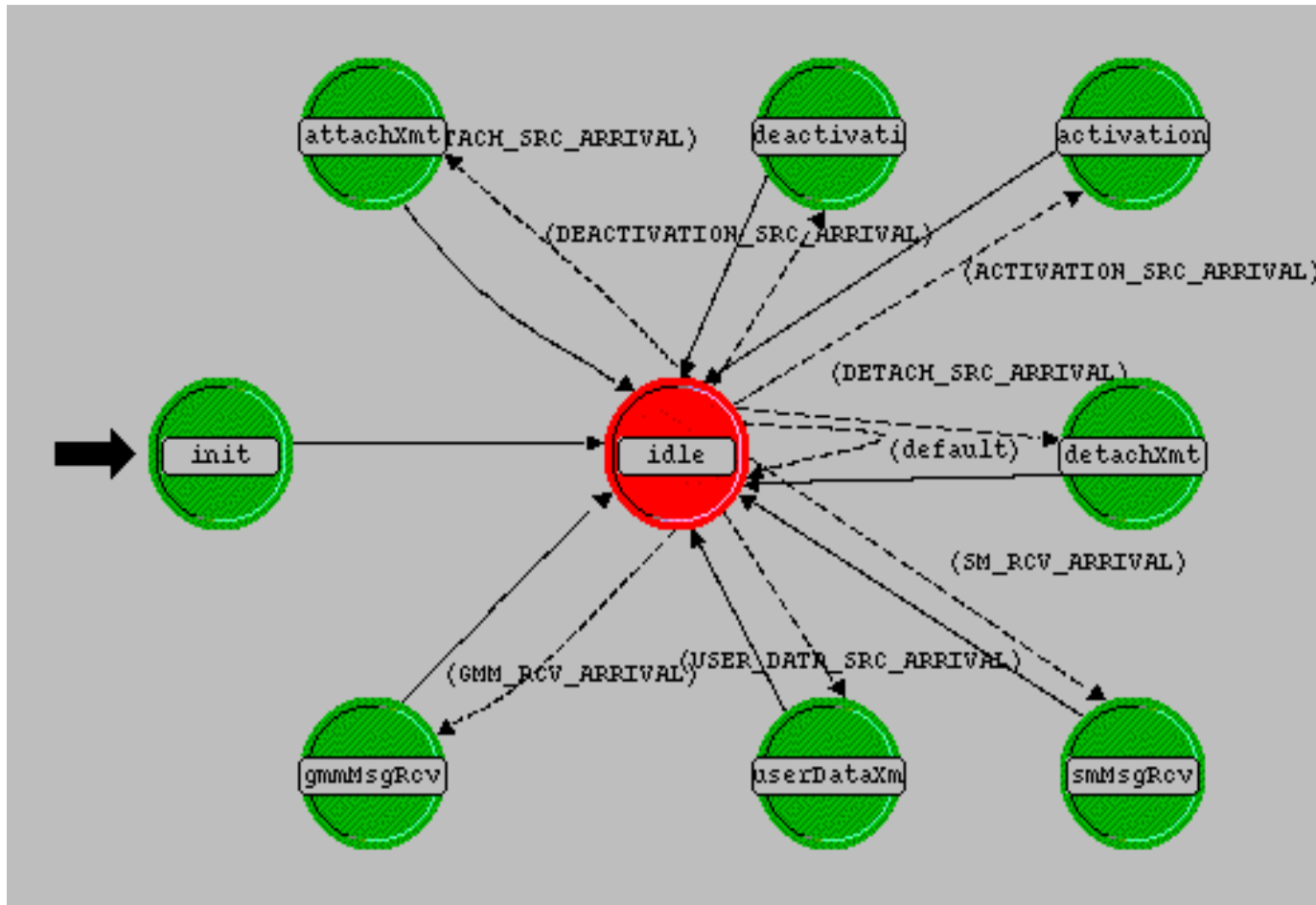


MS node model



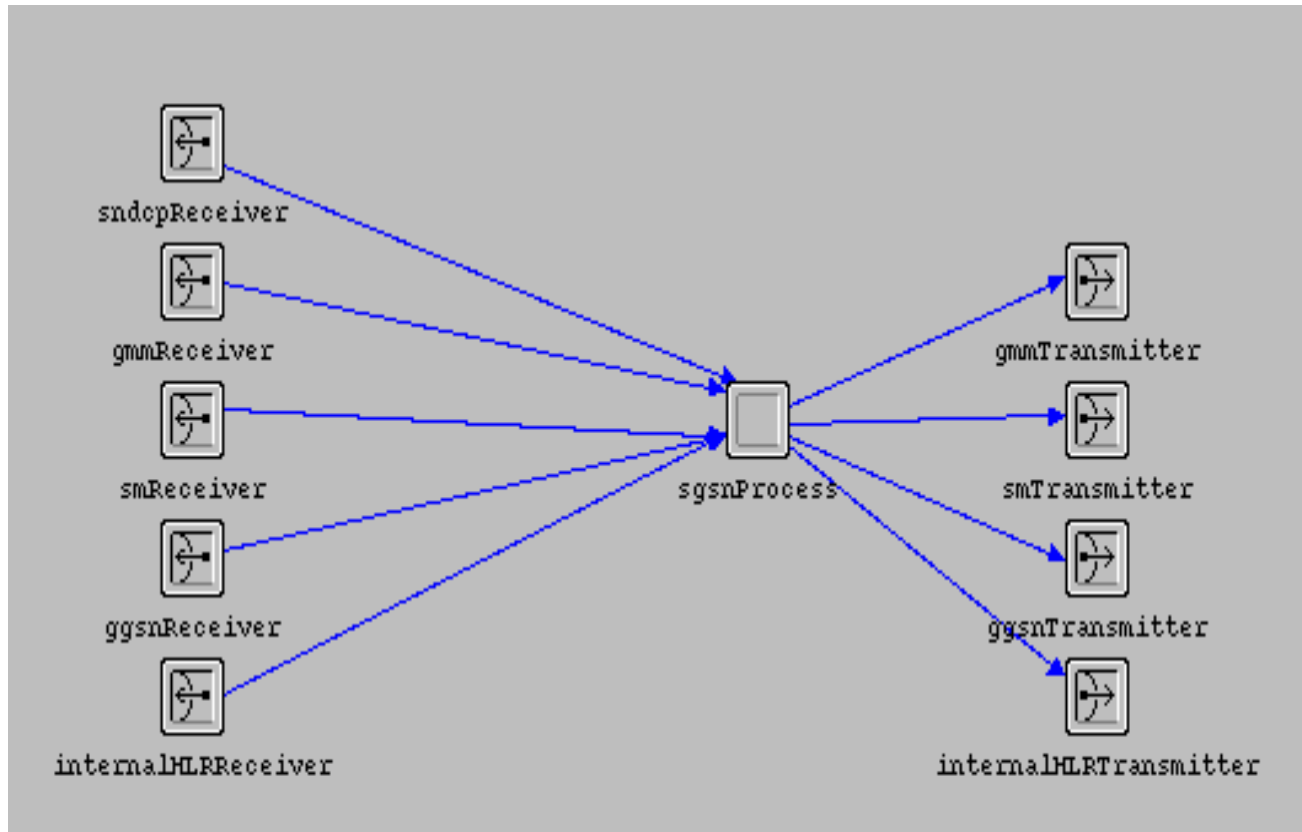


MS process model



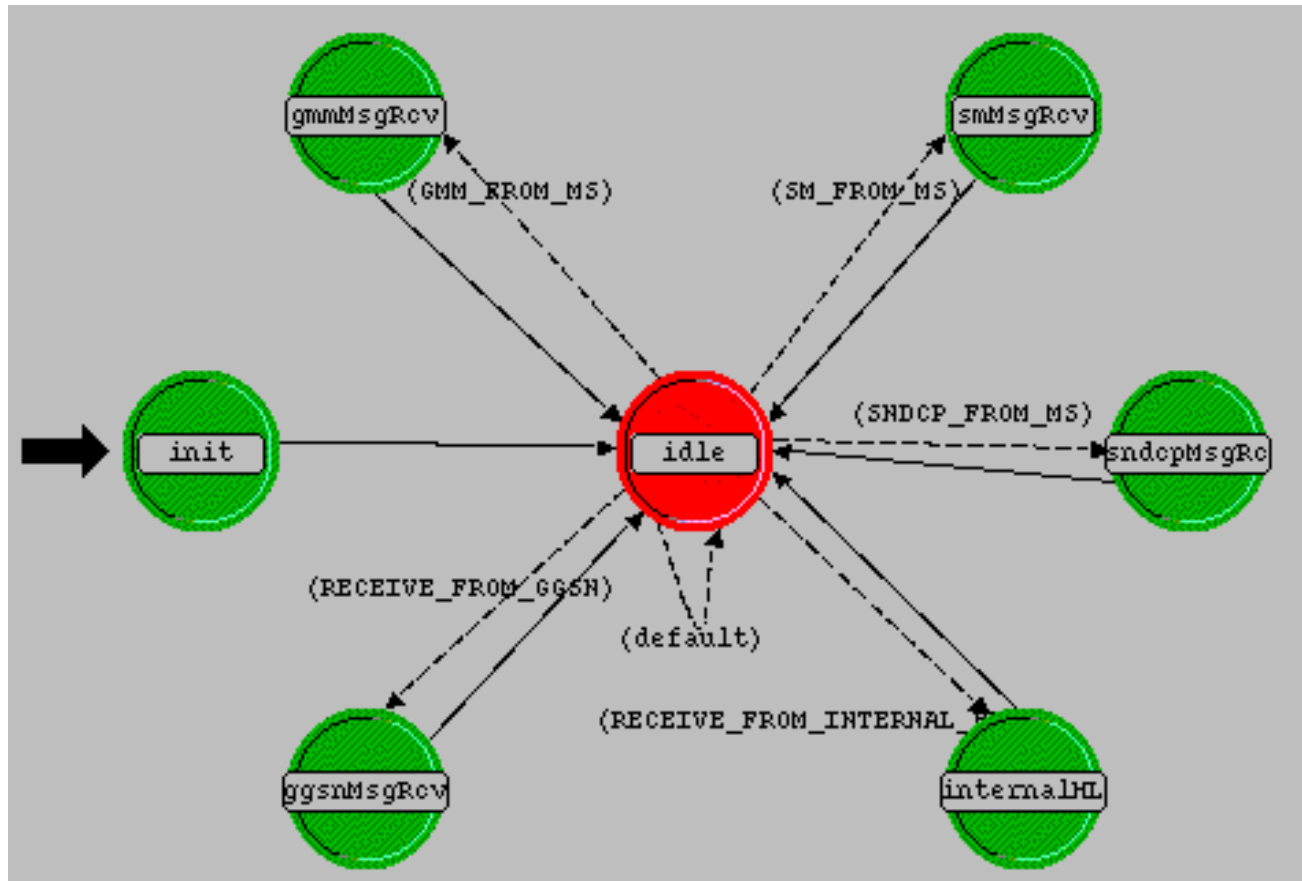


SGSN node model



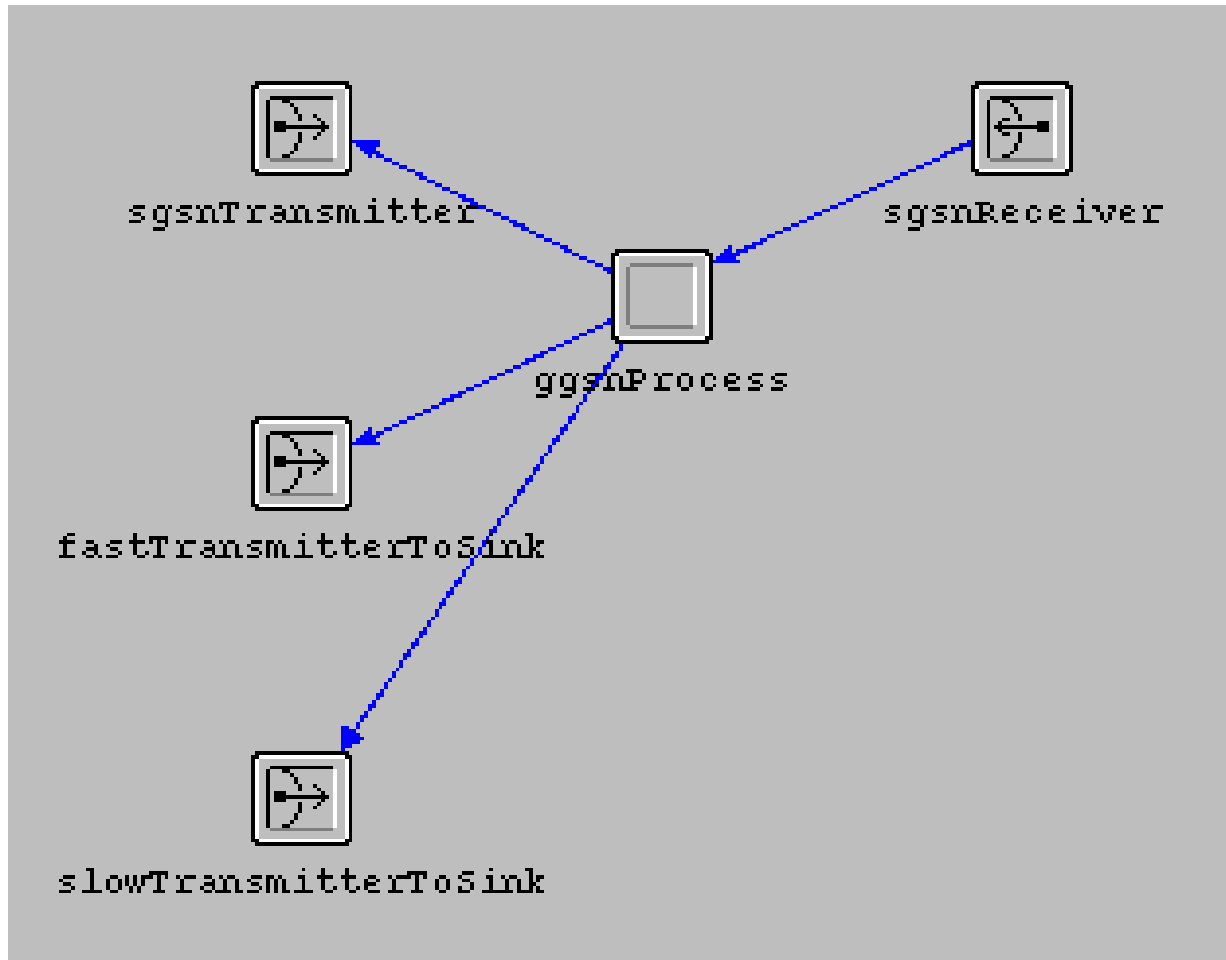


SGSN process model



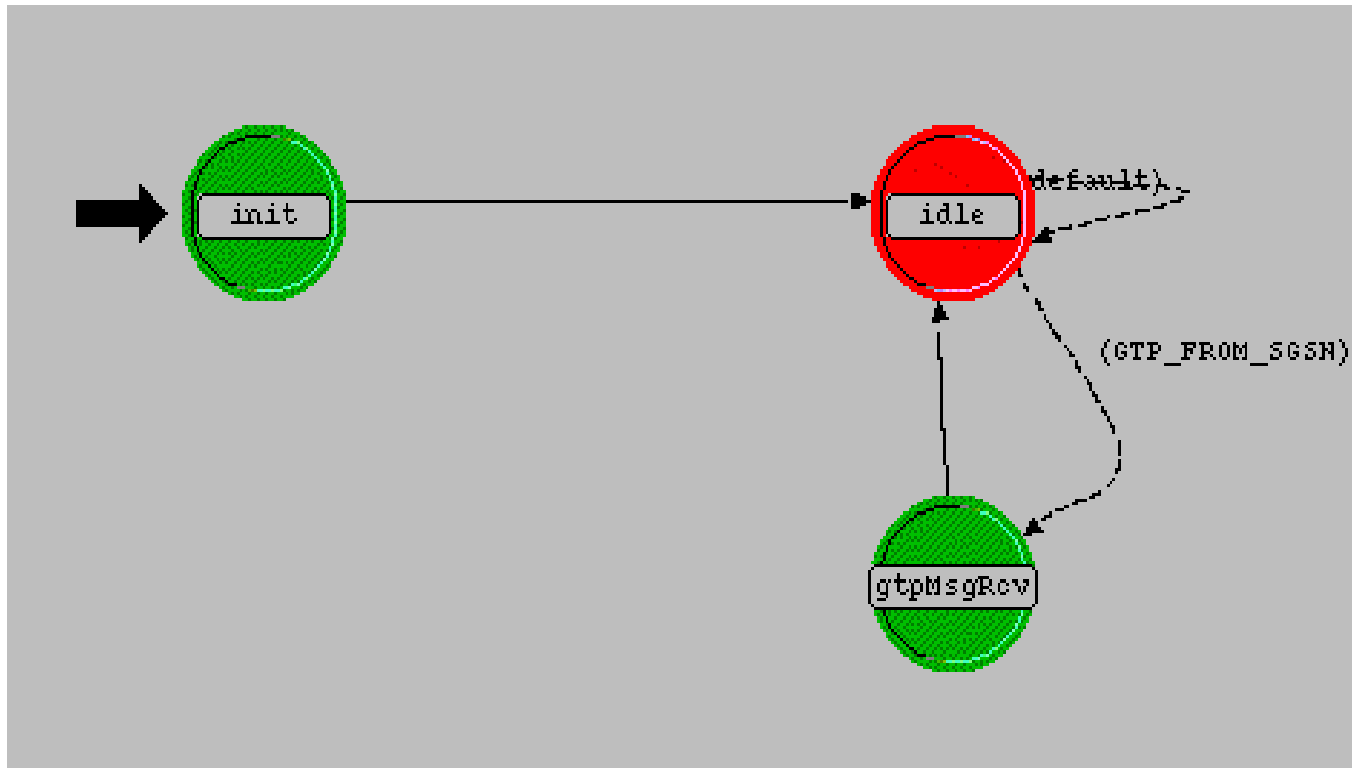


GGSN node model



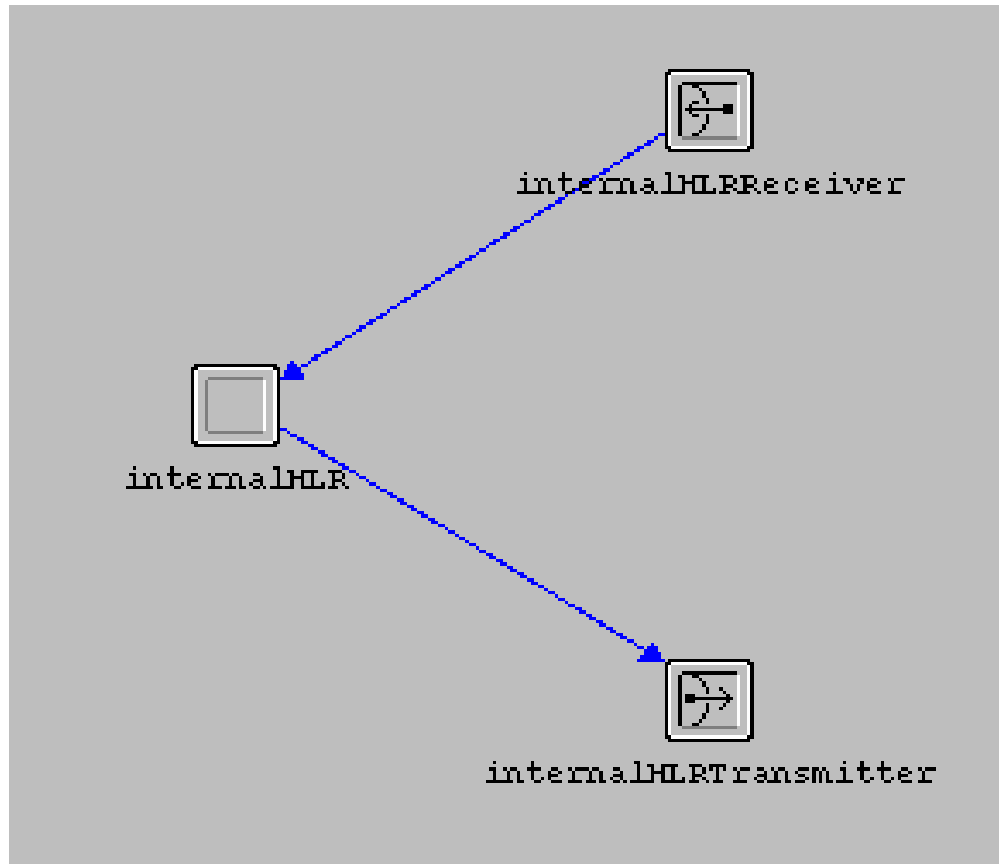


GGSN process model



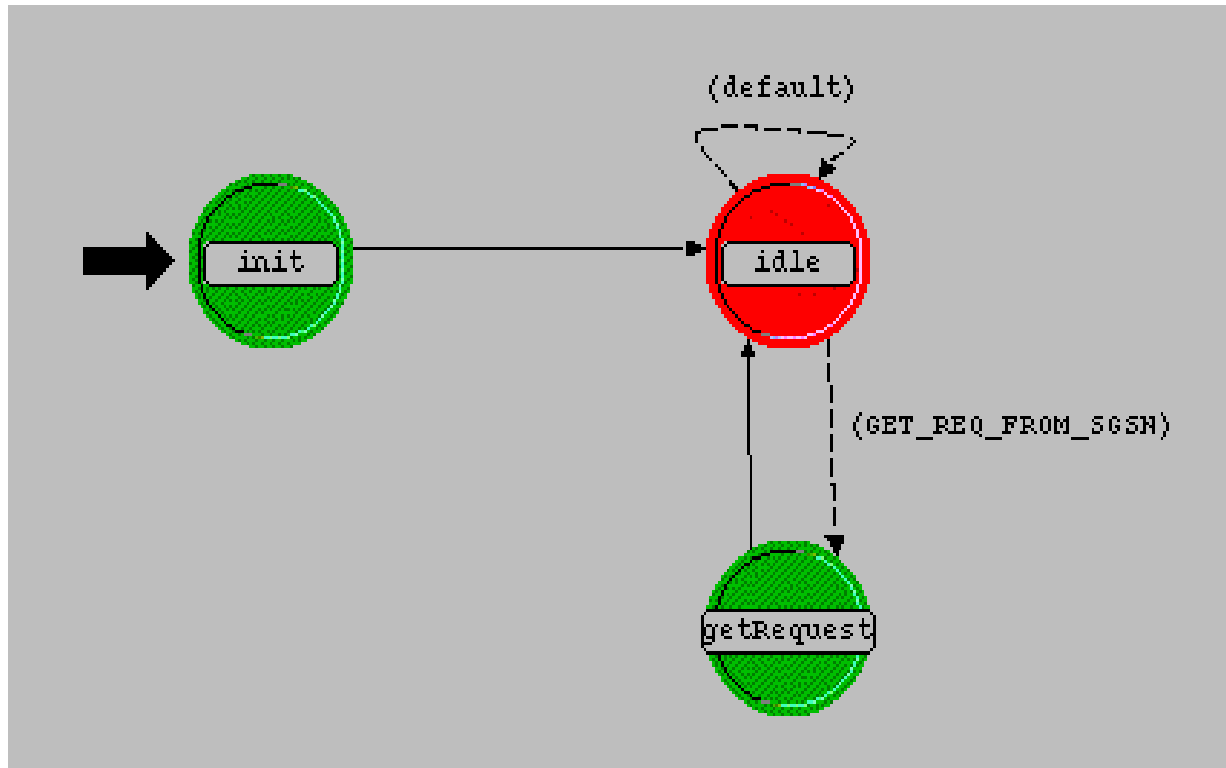


HLR node model





HLR process model



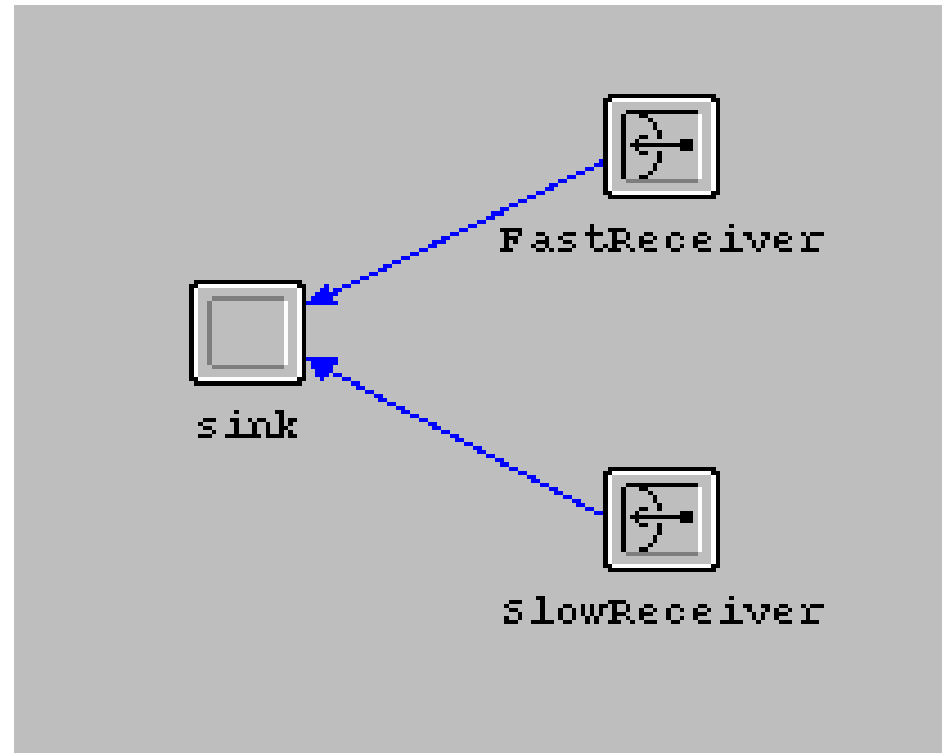


InternalHLR.gdf file

```
# 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
```

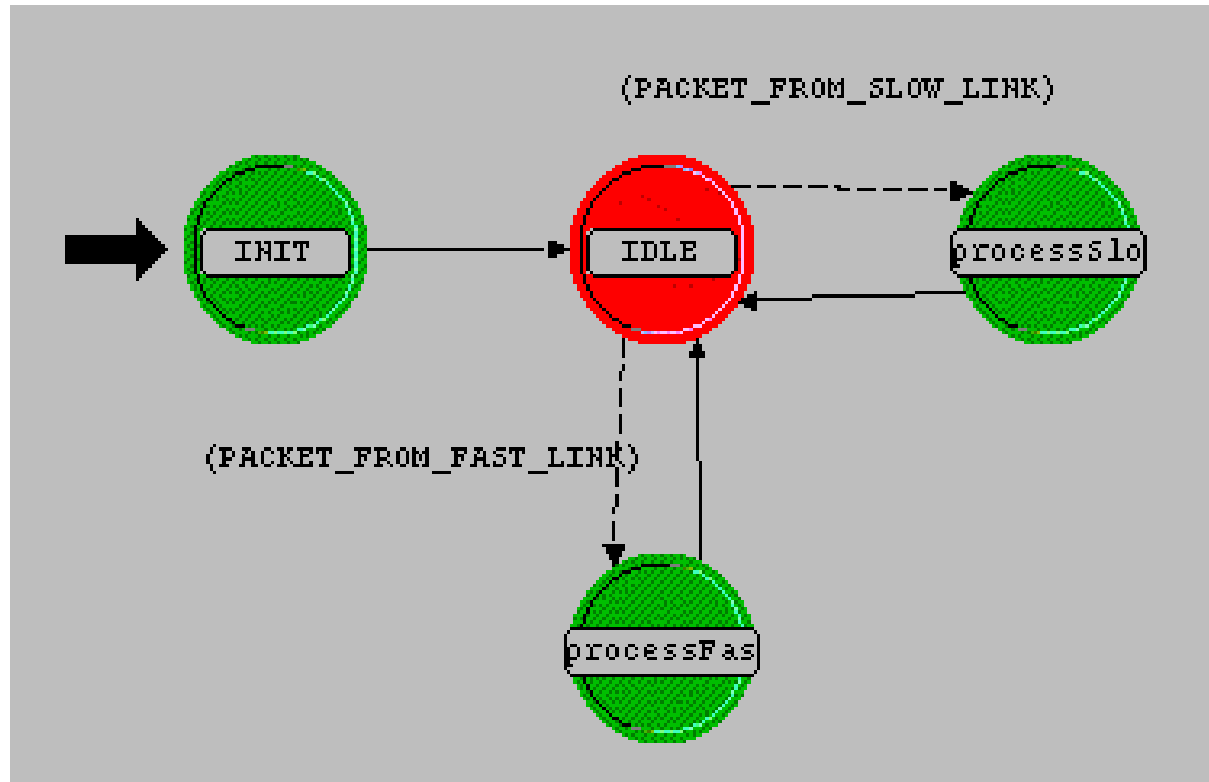


Sink node model



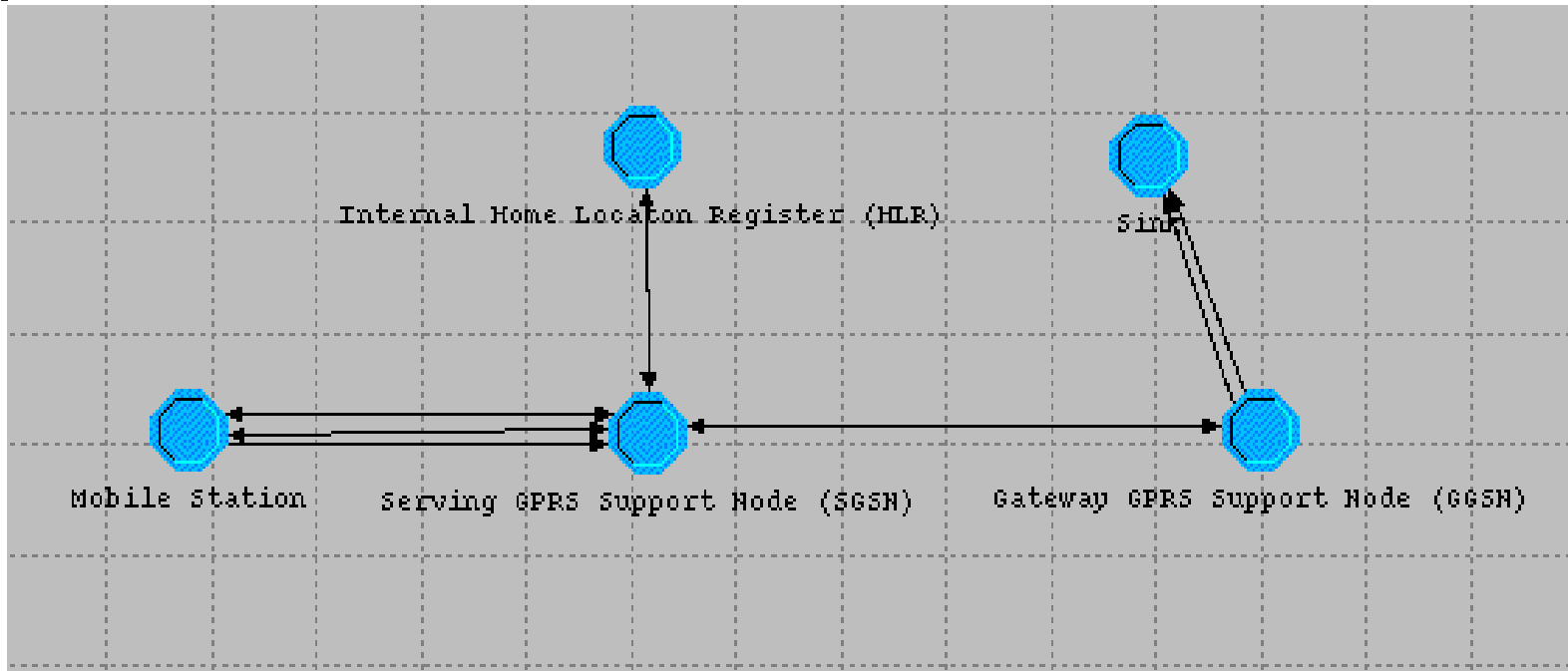


Sink process model





GPRS model project view





Simulation input window

Simulation Set: scenario

Name:

Number of runs in set: 1

Sim program:

Simulation set info...

Network:

Attribute	Value
-----------	-------

Probe file:

Vector file:

Scalar file:

Seed:

Duration:

Update interval:

Animation attributes...

Environment files...

Service Level Agreements...

Reports...

Date/Time...

Add... Expand... Delete

Update View Props Values...

Use default values for unresolved attributes

Save vector file for each run in set

Enable simulation logging

Parallel simulation: Processors

Use TMM propagation modeling

Cancel OK



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 $\geq 50,000$ 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



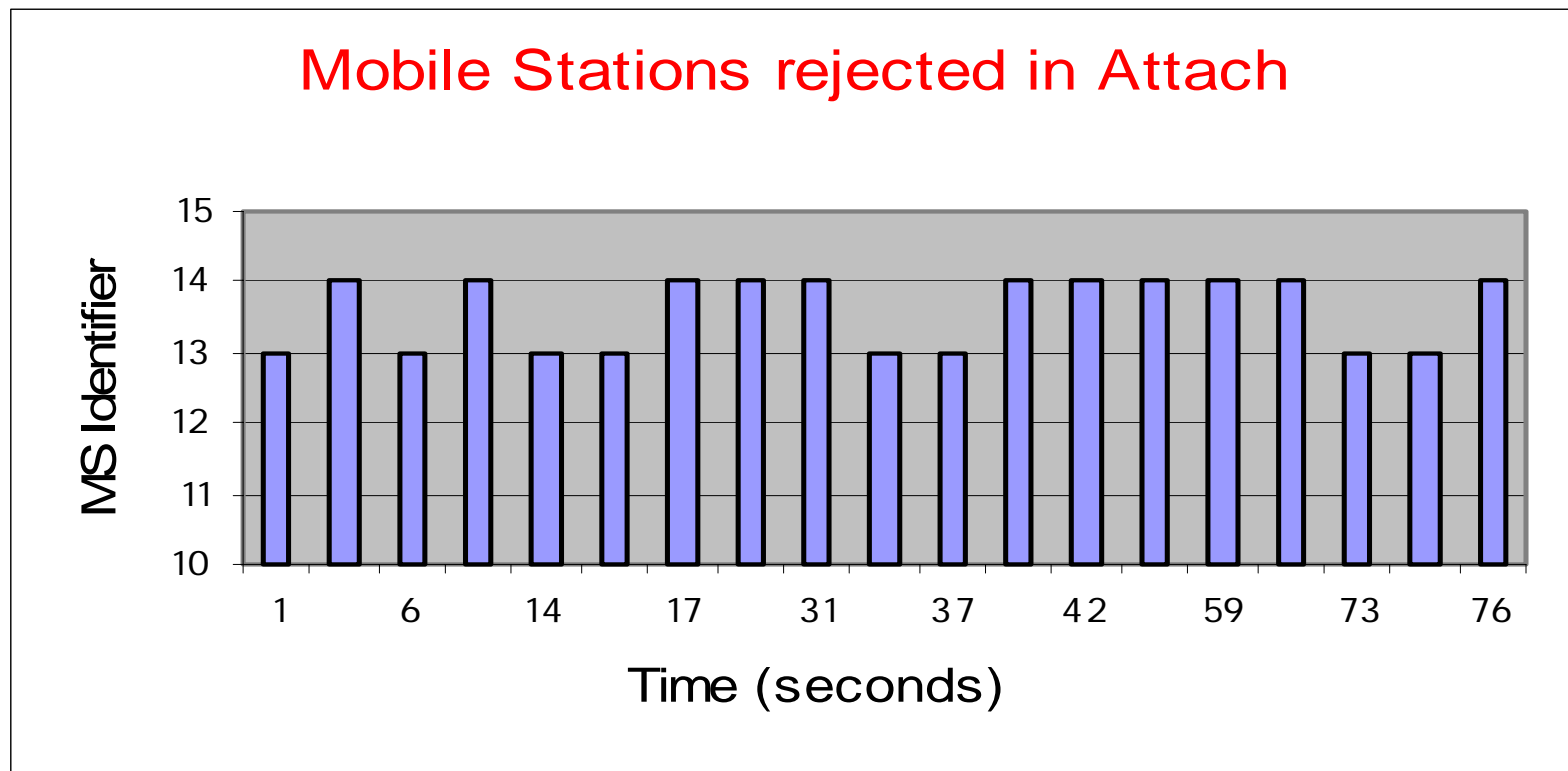
Simulation Scenario 1

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

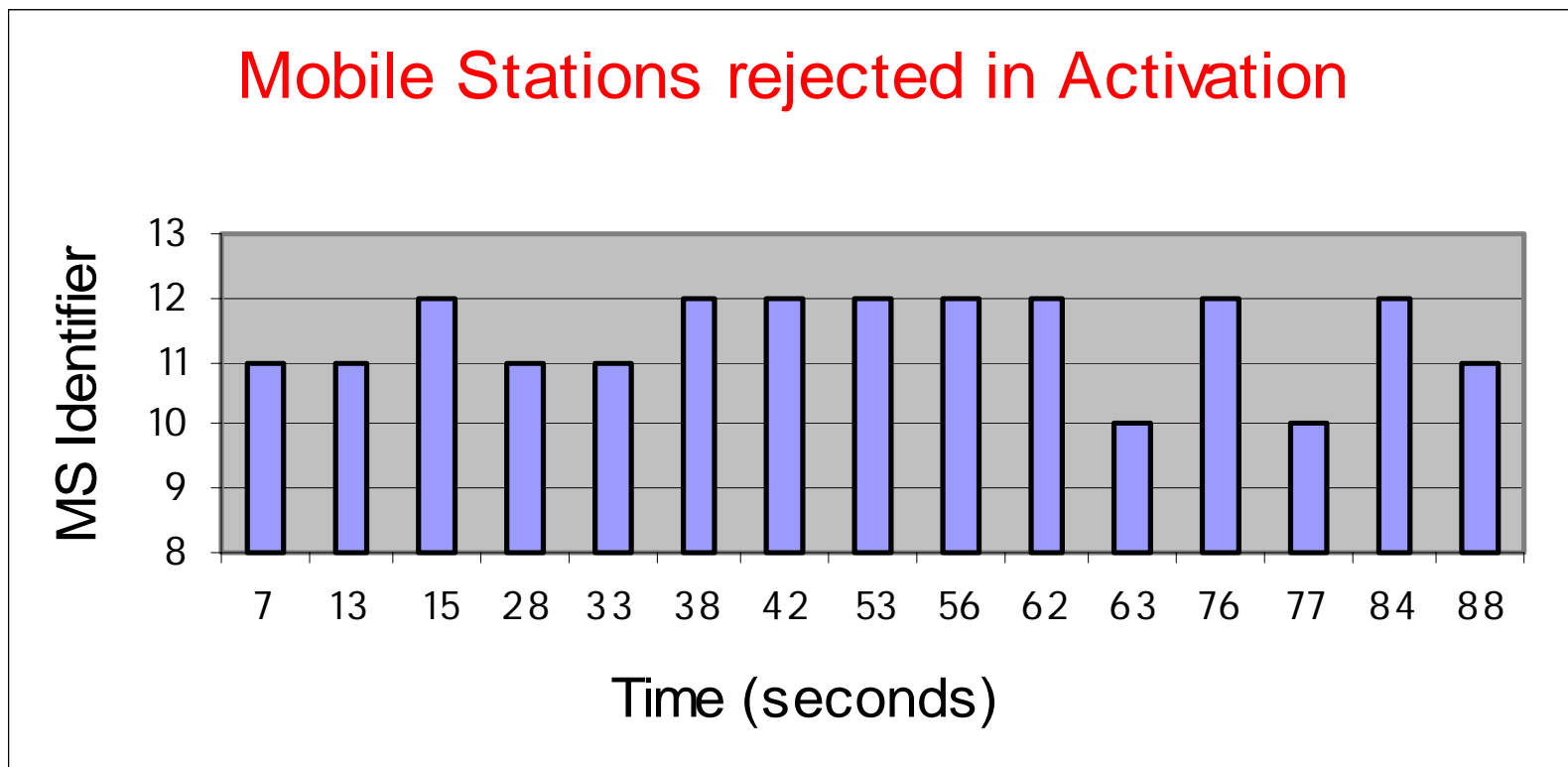


Rejection in Attach

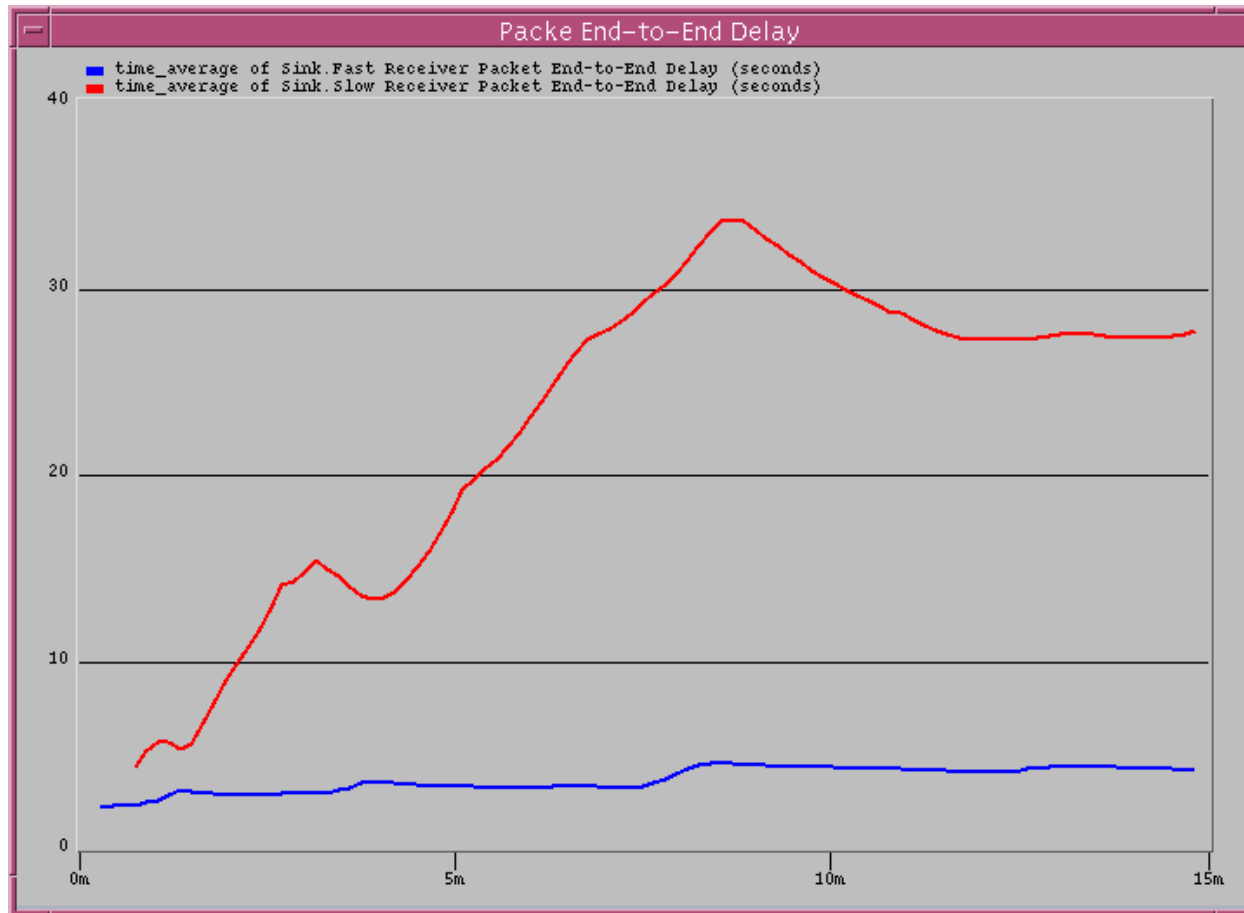




Rejection in Activation



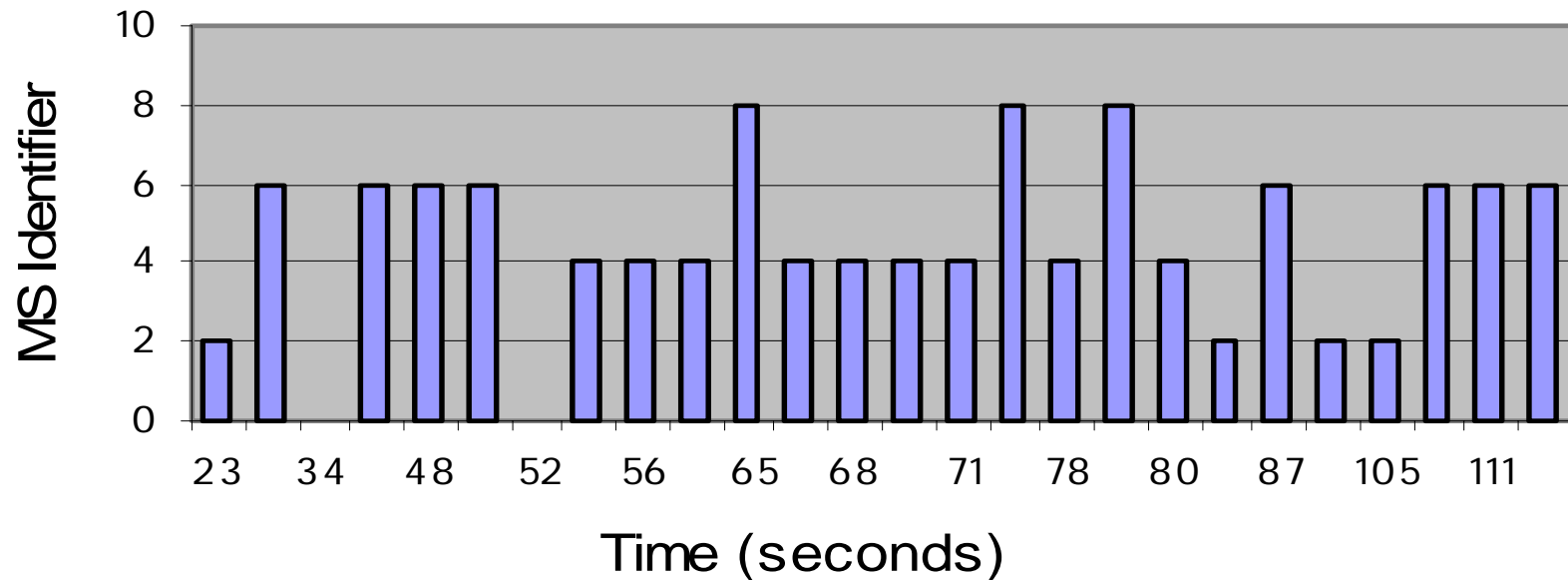
Two classes of QoS: packet end-to-end delays



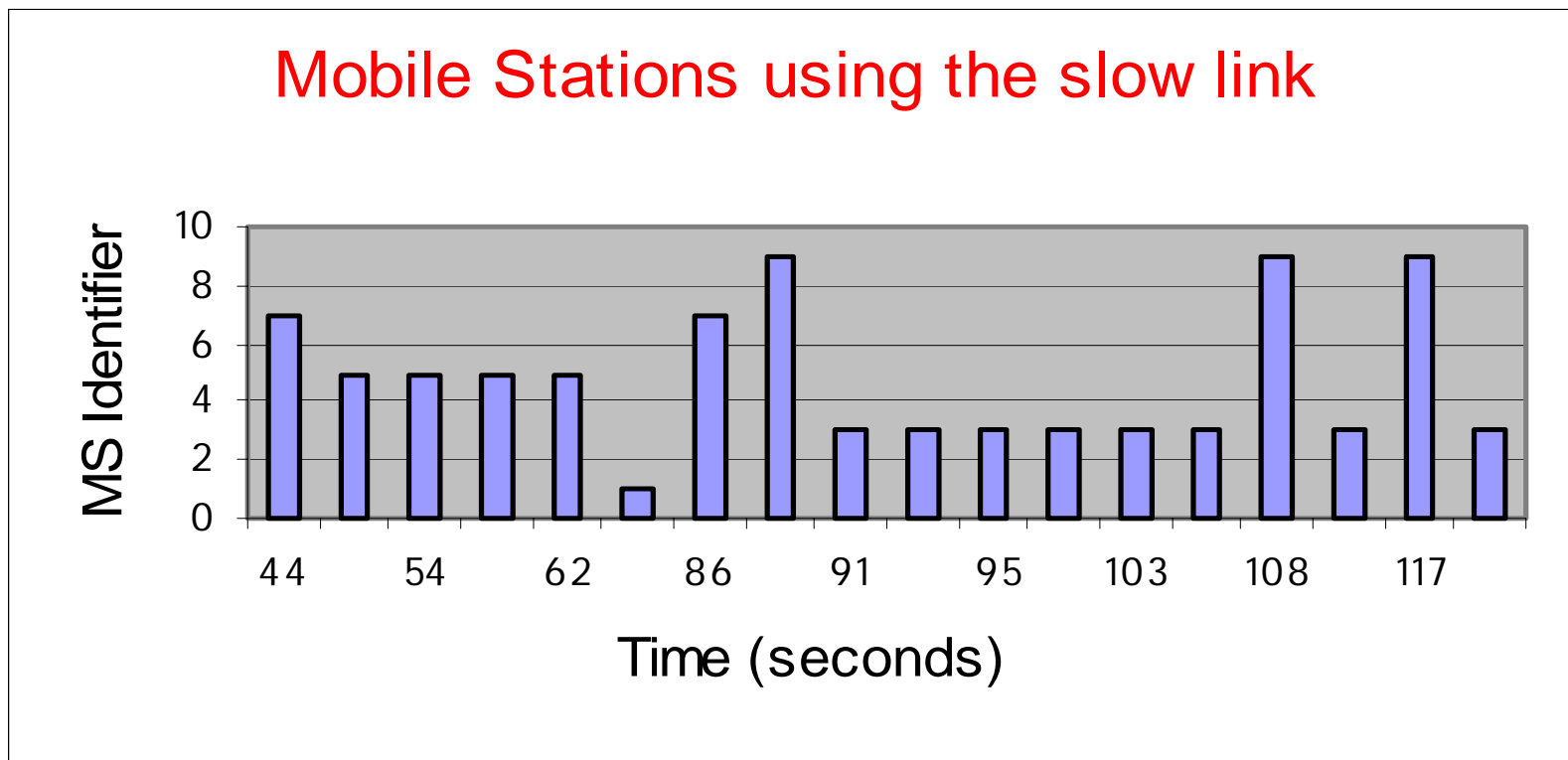
Two classes of QoS: Mobile Stations using the fast link



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
```



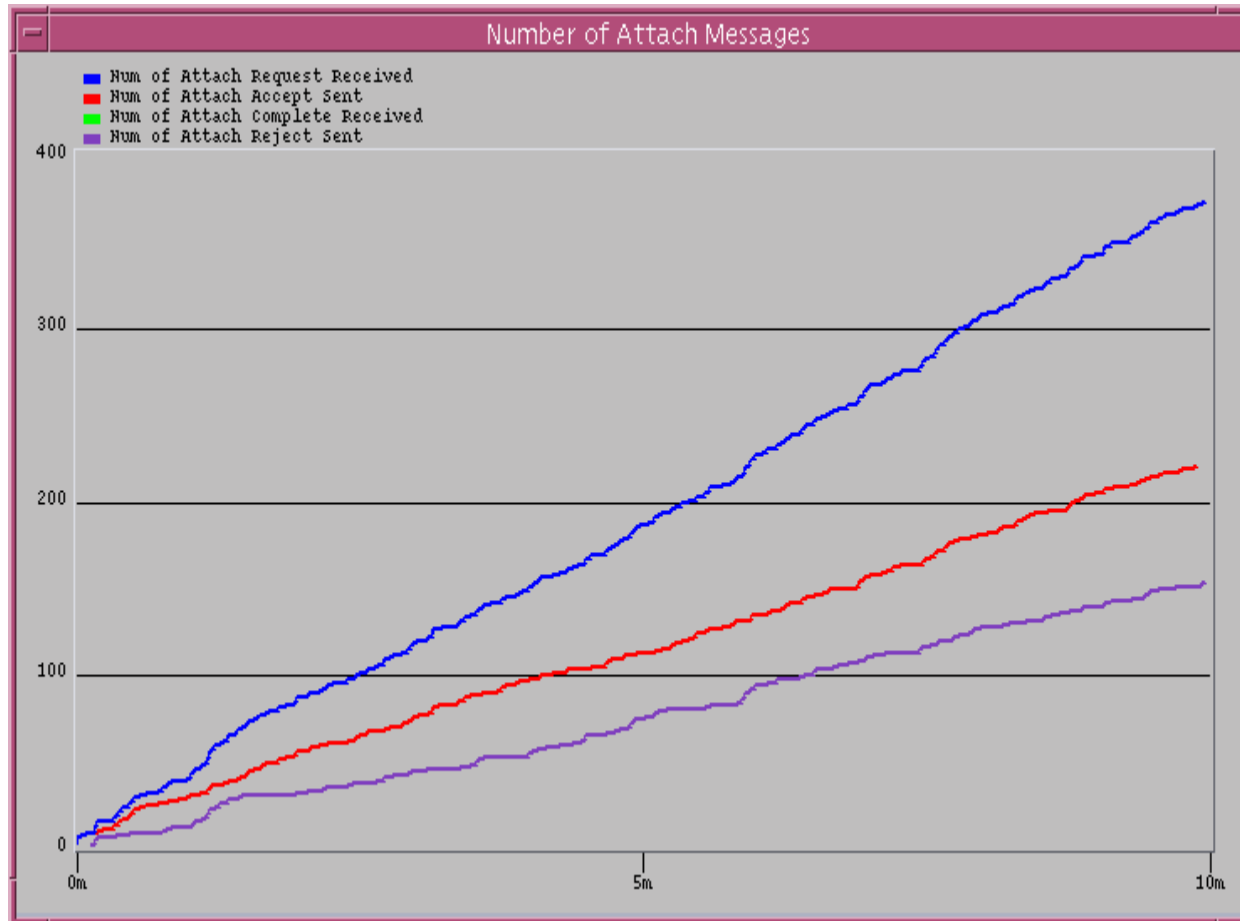
Simulation Scenario 2

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

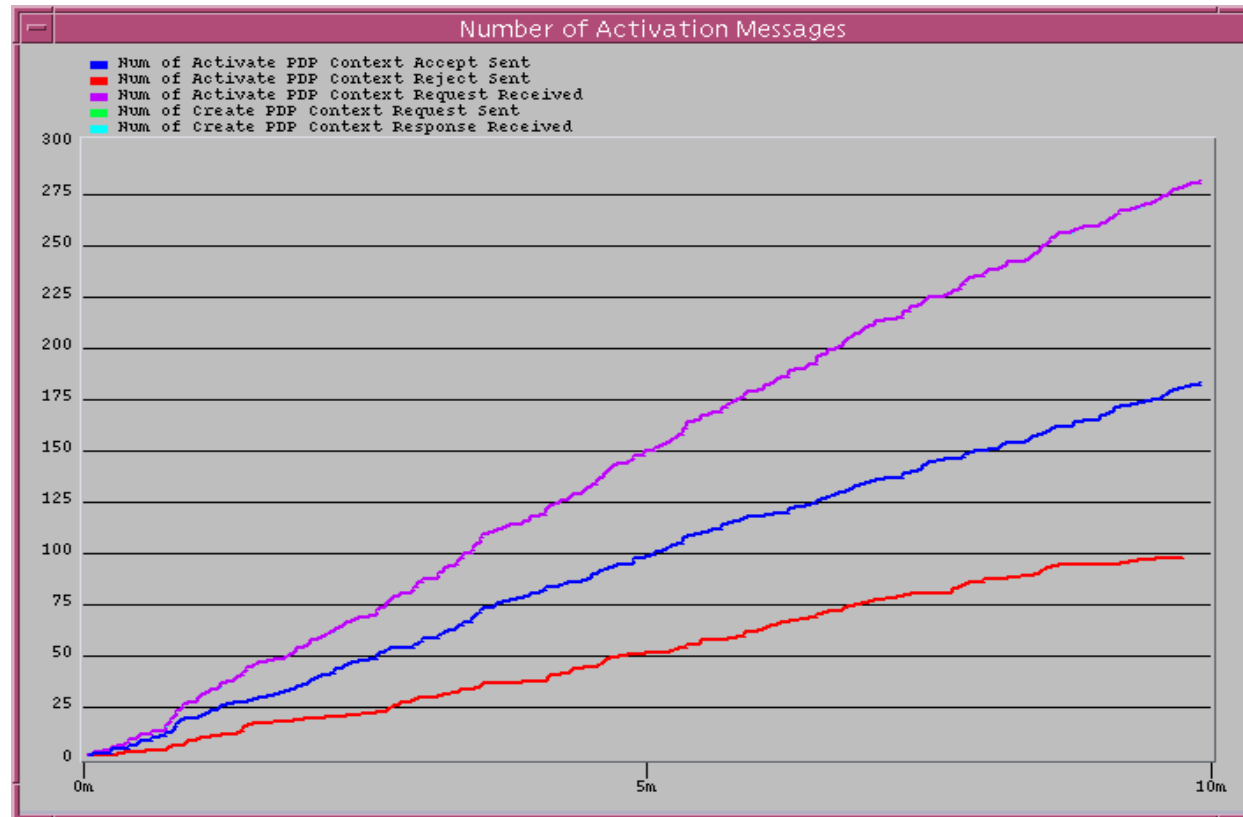


Number of Attach messages



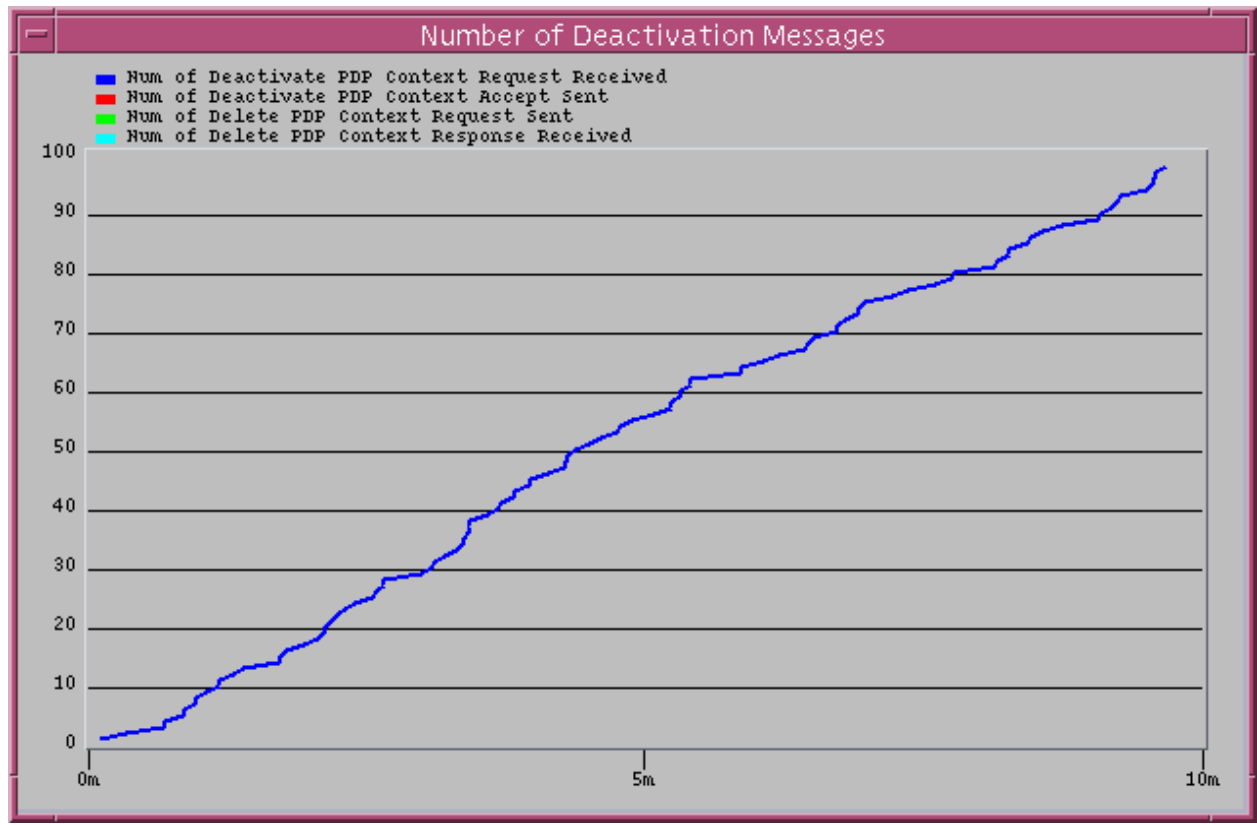


Number of Activation messages



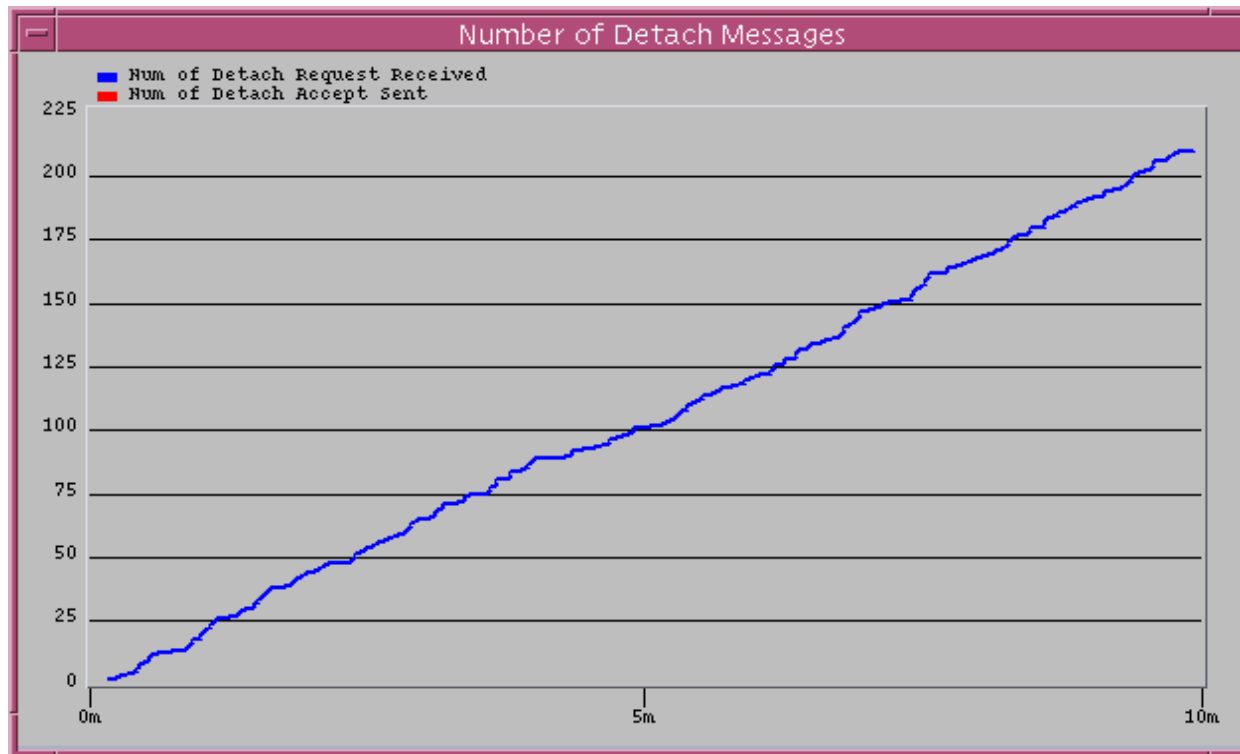


Number of Deactivation messages

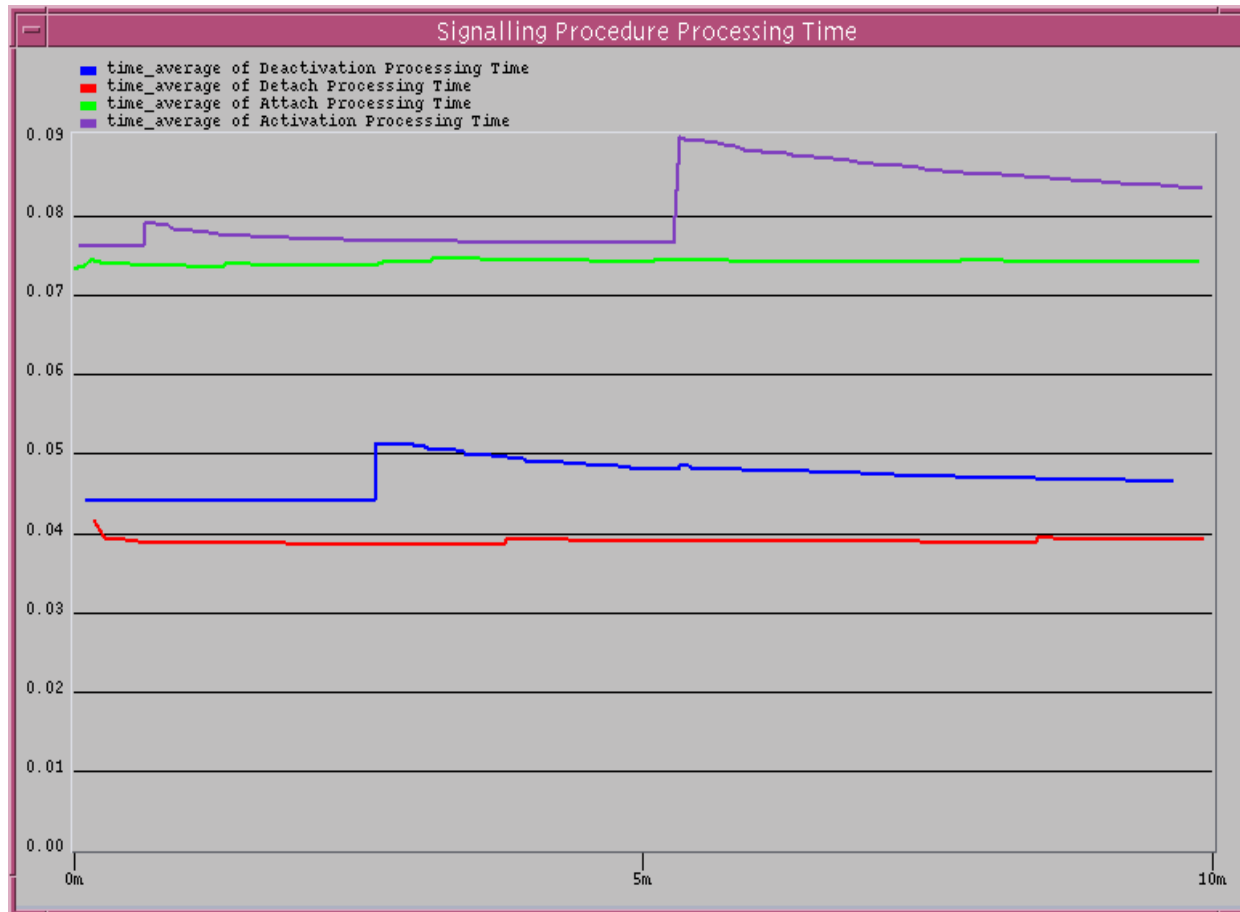




Number of Detach messages



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.