Outline

- GSM and GSM reference model
- GPRS basics
- Handoffs
  - GSM
  - GPRS
    - Location and Mobility Management
    - Re-selection and routing update
    - QoS
2.5 G – Provide data service

- **The GSM family**
  - Basic GSM: 9.6 kbps
  - HSCSD: 28.8 kbps / Circuit switched
  - GPRS: 40 kbps
  - EDGE: 384 kbps

- **The D-AMPS/ IS-136 Family**
  - CDPD: 9.6 kbps / 19.2 kbps
  - EDGE: 384 kbps

- **The IS-95 Family**
  - IS-95a – 9.6 kbps
  - IS-95b – 115.2 kbps
  - IS-95c / HDR – 2Mbps
The Cellular Network

- **MS** – Mobile Station
- **BTS** – Base Station Transceiver Station
- **BSC** – Base Station Controller
- **MSC** – Mobile Switching Center
- **HLR** – Home Location Register
- **VLR** – Visitor Location Register
- **EIR** – Equipment Identity Register
- **AuC** – Authentication Center

**Diagram:**
- MS
- BTS
- BSC
- Other MSC
- MSC
- EIR
- HLR
- VLR
- AuC
- Other VLRs
- External Networks
Basic GSM reference model

- SIM – Subscriber Identity Module
- GCR - Group Call Register
- IWF – InterWorking Function
- SIWF – Shared IWF
- GMSC - Gateway MSC
- SMS – Short Message Service
- SC – Service Center
GSM/GPRS reference model

- **TE** – Terminal Equipment
- **PDN** – Public Data Network
- **SGSN** – Serving GPRS Support Node
- **GGSN** – Gateway GPRS support Node
GPRS Data Rate

CS-1  9,05 kbps
CS-2  13,4 kbps
CS-3  15,6 kbps
CS-4  21,4 kbps

1-8 channel

171,2 kbps in theory
GPRS Protocol Stack

Network Layer
SNDCP
LLC
RLC
MAC
PLL
RFL
MS

Base Station

SNDCP
LLC
RLC
MAC
PLL
RFL

Network Layer
GTP
TCP/UDP
IP
L2
PHY

SGSN

GTP
TCP/UDP
IP
L2
PHY

GGSN

PSPDN Specific Protocols

MAC – Medium Access Control
- Backward Error Control-ARQ
- Slotted ALOHA
- Master-Slave concept
- Capacity on demand
- Multiframe structure for PDCH

RLC – Radio Link Control
- Burst Interleaving
- Link congestion detection
GPRS Protocol Stack

GTP
GPRS Tunneling Protocol

SNDCP
Sub-Network Dependent Convergence Protocol

Network Layer

SNDCP

LLC

BSSGP

FR

PHY

PSPDN Specific Protocols

GTP

TCP/UDP

IP

L2

PHY

GGSN
Handoffs in GSM and GPRS
GSM

- **Types (network elements)**
  - Intracell HO
  - Inter-Cell HO within the same BSC
  - Intra MSC HO
  - Inter MSC HO

- **Types (function location)**
  - Mobile initiated
  - Network initiated, mobile assisted
GSM (cont.)

- Measurements of the Broadcast Channel on a free time slot
- Decision according to:
  - Minimum acceptable performance
    power control is preferred over HO
  - Power budget algorithms
    HO is preferred over power control
GSM Handover Initiation

- Initiation by the network providing
  - New channels characteristics
  - Characteristics of a new cell
  - Power level
  - Physical channel establishment procedures
  - Timing advance
  - Cipher mode setting
Physical Channel Establishment

- Finely synchronized cells
- Non synchronized cells
- *Pseudo synchronized cells*
- Pre-synchronized cells
GPRS
Mobile Station Modes of Operation

- **Class A**: The MS is attached to both GSM and GPRS simultaneously
- **Class B**: The MS is attached to both but can operate in only one at a time
- **Class C**: The MS is attached to GPRS or other GSM services
Cell Hierarchy

Location Area

Routing Area

Location Area
Levels of Location Management

- **Cell Update** (re-selection procedure)
  - Originated by MS
  - Based on BCCH measurements
  - Other criteria may apply

- **Routing Area update**
  - Initiated by mobile when crossing RA boundary
Mobility Management States

- **Idle**
  - MS is not attached to GPRS

- **Standby**
  - Subscriber is attached to GPRS mobility management
  - MS performs RA and cell selection locally, reports RA changes
  - Data, signaling or page response move the MS to READY
  - Detach procedures moves the state to Idle

- **Ready**
  - Information on cell selection is reported
  - Cell selection may be done locally or by network control
  - State supervised by a timer
Mobility Management States

- **IDLE**
  - GPRS Attach
  - GPRS Detach

- **READY**
  - READY timer expiry or Force to STANDBY
  - PDU transmission

- **STANDBY**
GPRS Re-Selection

- GPRS IDLE state and wishes to initiate the GPRS Attach procedure:
  - If the currently camped-on cell supports GPRS then no cell reselection is required.
  - If the currently camped-on cell does not support GPRS, then reselection of a cell supporting GPRS is required before execution of the attach procedure.
- If the MS is in GPRS STANDBY or READY state, cell selection and reselection procedures specific to GPRS shall be used.
- The cell reselection procedure used in READY state shall minimise the cell changes.
- If the MS is in dedicated mode, then the changes from one cell to another is performed according to the network-controlled handover procedures.
- There may be co-ordination of the idle and dedicated mode procedures used for circuit-switched services with the READY state procedure for MSs that are both IMSI-attached and GPRS-attached.
Routing Update Procedure

- MS sends RA update request containing the cell identity and the identity of previous routing area, to new SGSN
- New SGSN asks from old SGSN the context (GGSN address and tunneling information) of the MS
- New SGSN updates GGSNs, new SGSN address and tunneling information is delivered to GGSN
- New SGSN updates HLR
- HLR cancels the MS information context in old SGSN
- HLR loads the subscriber data to new SGSN
- New SGSN acknowledges to the MS
- The previous SGSN is requested to transmit the undelivered data to the new SGSN.

www.ece.wpi.edu/~prashant/geo/neth98.pdf
QoS Profiles

- Precedence Class
  - High, Normal, Low
- Delay Classes
- Reliability Classes
- Throughput classes
## Delay Classes

<table>
<thead>
<tr>
<th>Delay Class</th>
<th>SDU size: 128 octets</th>
<th>SDU size: 1024 octets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Transfer Delay (sec)</td>
<td>95 percentile Delay (sec)</td>
</tr>
<tr>
<td>1. (Predictive)</td>
<td>&lt; 0.5</td>
<td>&lt; 1.5</td>
</tr>
<tr>
<td>2. (Predictive)</td>
<td>&lt; 5</td>
<td>&lt; 25</td>
</tr>
<tr>
<td>3. (Predictive)</td>
<td>&lt; 50</td>
<td>&lt; 250</td>
</tr>
<tr>
<td>4. (Best Effort)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Reliability Classes

<table>
<thead>
<tr>
<th>Reliability class</th>
<th>Lost SDU probability (a)</th>
<th>Duplicate SDU probability</th>
<th>Out of Sequence SDU probability</th>
<th>Corrupt SDU probability (b)</th>
<th>Example of application characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10^-9</td>
<td>10^-9</td>
<td>10^-9</td>
<td>10^-9</td>
<td>Error sensitive, no error correction capability, limited error tolerance capability.</td>
</tr>
<tr>
<td>2</td>
<td>10^-4</td>
<td>10^-5</td>
<td>10^-5</td>
<td>10^-6</td>
<td>Error sensitive, limited error correction capability, good error tolerance capability.</td>
</tr>
<tr>
<td>3</td>
<td>10^-2</td>
<td>10^-5</td>
<td>10^-5</td>
<td>10^-2</td>
<td>Not error sensitive, error correction capability and/or very good error tolerance capability.</td>
</tr>
</tbody>
</table>
## Reliability Classes (cont.)

<table>
<thead>
<tr>
<th>Reliability Class</th>
<th>GTP Mode</th>
<th>LLC Frame Mode</th>
<th>LLC Data Protection</th>
<th>RLC Block Mode</th>
<th>Traffic Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Acknowledged</td>
<td>Acknowledged</td>
<td>Protected</td>
<td>Acknowledged</td>
<td>Non real-time traffic, error-sensitive application that cannot cope with data loss.</td>
</tr>
<tr>
<td>2</td>
<td>Unacknowledged</td>
<td>Acknowledged</td>
<td>Protected</td>
<td>Acknowledged</td>
<td>Non real-time traffic, error-sensitive application that can cope with infrequent data loss.</td>
</tr>
<tr>
<td>3</td>
<td>Unacknowledged</td>
<td>Unacknowledged</td>
<td>Protected</td>
<td>Acknowledged</td>
<td>Non real-time traffic, error-sensitive application that can cope with data loss, GMM/SM, and SMS.</td>
</tr>
<tr>
<td>4</td>
<td>Unacknowledged</td>
<td>Unacknowledged</td>
<td>Protected</td>
<td>Unacknowledged</td>
<td>Real-time traffic, error-sensitive application that can cope with data loss.</td>
</tr>
<tr>
<td>5</td>
<td>Unacknowledged</td>
<td>Unacknowledged</td>
<td>Unprotected</td>
<td>Unacknowledged</td>
<td>Real-time traffic, error non-sensitive application that can cope with data loss.</td>
</tr>
</tbody>
</table>

*NOTE:* For real-time traffic, the QoS profile also requires appropriate settings for delay and throughput.
# Peak Throughput Class

<table>
<thead>
<tr>
<th>Peak Throughput Class</th>
<th>Peak Throughput in octets per second</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Up to 1 000 (8 kbit/s).</td>
</tr>
<tr>
<td>2</td>
<td>Up to 2 000 (16 kbit/s).</td>
</tr>
<tr>
<td>3</td>
<td>Up to 4 000 (32 kbit/s).</td>
</tr>
<tr>
<td>4</td>
<td>Up to 8 000 (64 kbit/s).</td>
</tr>
<tr>
<td>5</td>
<td>Up to 16 000 (128 kbit/s).</td>
</tr>
<tr>
<td>6</td>
<td>Up to 32 000 (256 kbit/s).</td>
</tr>
<tr>
<td>7</td>
<td>Up to 64 000 (512 kbit/s).</td>
</tr>
<tr>
<td>8</td>
<td>Up to 128 000 (1 024 kbit/s).</td>
</tr>
<tr>
<td>9</td>
<td>Up to 256 000 (2 048 kbit/s).</td>
</tr>
</tbody>
</table>
# Mean Throughput Classes

<table>
<thead>
<tr>
<th>Mean Throughput Class</th>
<th>Mean Throughput in octets per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 (~0.22 bit/s).</td>
</tr>
<tr>
<td>2</td>
<td>200 (~0.44 bit/s).</td>
</tr>
<tr>
<td>3</td>
<td>500 (~1.11 bit/s).</td>
</tr>
<tr>
<td>4</td>
<td>1 000 (~2.2 bit/s).</td>
</tr>
<tr>
<td>5</td>
<td>2 000 (~4.4 bit/s).</td>
</tr>
<tr>
<td>6</td>
<td>5 000 (~11.1 bit/s).</td>
</tr>
<tr>
<td>7</td>
<td>10 000 (~22 bit/s).</td>
</tr>
<tr>
<td>8</td>
<td>20 000 (~44 bit/s).</td>
</tr>
<tr>
<td>9</td>
<td>50 000 (~111 bit/s).</td>
</tr>
<tr>
<td>10</td>
<td>100 000 (~0.22 kbit/s).</td>
</tr>
<tr>
<td>11</td>
<td>200 000 (~0.44 kbit/s).</td>
</tr>
<tr>
<td>12</td>
<td>500 000 (~1.11 kbit/s).</td>
</tr>
<tr>
<td>13</td>
<td>1 000 000 (~2.2 kbit/s).</td>
</tr>
<tr>
<td>14</td>
<td>2 000 000 (~4.4 kbit/s).</td>
</tr>
<tr>
<td>15</td>
<td>5 000 000 (~11.1 kbit/s).</td>
</tr>
<tr>
<td>16</td>
<td>10 000 000 (~22 kbit/s).</td>
</tr>
<tr>
<td>17</td>
<td>20 000 000 (~44 kbit/s).</td>
</tr>
<tr>
<td>18</td>
<td>50 000 000 (~111 kbit/s).</td>
</tr>
<tr>
<td>31</td>
<td>Best effort.</td>
</tr>
</tbody>
</table>
Handoff Summary

- No special probe signal is used by BTS (MCHO)
- Several principles are used for handoff decision
- Only passive scanning at MS is employed to detect nearby BTS (like in GSM)
- In network layer MS communicates with SGSN, in physical layer with a BSS.
- Several protocols and channels are employed for indicating the MSs current location
<table>
<thead>
<tr>
<th></th>
<th>802.11</th>
<th>GSM/GPRS</th>
<th>CDPD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beacon</strong></td>
<td>Same physical channel</td>
<td>Separate Physical Channel</td>
<td>Separate Physical Channel</td>
</tr>
<tr>
<td><strong>Handoff</strong></td>
<td>Mobile</td>
<td>GSM - BSC</td>
<td>Mobile</td>
</tr>
<tr>
<td><strong>Decision</strong></td>
<td></td>
<td>GPRS - MS</td>
<td></td>
</tr>
<tr>
<td><strong>Information to</strong></td>
<td>IAPP</td>
<td>GSM – by BSC</td>
<td>Message from MHF to MSF of old BS</td>
</tr>
<tr>
<td><strong>old AP</strong></td>
<td></td>
<td>GPRS – by SGSN</td>
<td></td>
</tr>
<tr>
<td><strong>Channel</strong></td>
<td>At the terminal</td>
<td>At the terminal</td>
<td>At the terminal</td>
</tr>
<tr>
<td><strong>Monitoring</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Access and</strong></td>
<td>CSMA Monitored all the time</td>
<td>TDMA Monitored when MS does not transmit or receive</td>
<td>DSMA/CD Monitored all the time</td>
</tr>
<tr>
<td><strong>Monitoring</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusion

- Wireless data has been considered since early days of cellular technology
- GSM/GPRS supports packet data together with CS traffic, with rates up to 171kbps
- Handover in GPRS is strongly aligned to GSM handover
- QoS is the main issue in handover of GPRS. The standard supports a variety of profiles
- HO principles are similar in various types of systems