Mobile Broadband driven by Convergence of IP and LTE technologies

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Today’s Topics

- Mobile Broadband and IP Convergence
- Technology Details
Key Takeaways

1. Mobile Broadband is next big global phenomena

2. IP & LTE Technologies enable convergence

3. Ericsson is committed to drive ecosystem globally towards 50B Connections in 2020
Broadband goes mobile
From household to individuals and devices

Mobile dominates broadband access in 2014

Source: Q2 2009 Ericsson
Ericsson North America
Increased Momentum in 2009

Network Transformation
AT&T, T-Mobile Partner
AT&T Wireline Domain Partner
Verizon & Metro PCS LTE/EPC

Services Transformation
Sprint Wireline and Wireless

Increased R&D
Nortel CDMA and LTE Assets
Ericsson Silicon Valley: Mobility + IP + Broadband Convergence

Ericsson Operator Momentum with increased R&D
Ericsson Silicon Valley
Position

- Ericsson leadership in mobile communication
- Silicon Valley leadership in internet and IP

Ericsson complements Silicon Valley companies
Ericsson Silicon Valley

- Ericsson Global IP Business
- Ericsson Global Broadband Access
- Ericsson Global Transport & Optical
- Mobile Broadband & Applications
- Ecosystem – External Collaboration
- Ericsson Group Functions Technology, Research, Strategy, Marketing...

Headquarter Group Functions beyond Business Functions
Mobile Packet Networks – Flat IP

3G
- GGSN
- SGSN
- RNC
  - NodeB

SAE/LTE
- SAE-GW
- MME
- eNB
  - eNB

Core
- lub
- lur

RAN
- lub
- lub
- S1
- X2
LTE integrated with 2G/3G Mobile Networks
Smooth multi-access evolution

- LTE eNodeB
- GGSN to Packet Gateway
- SGSN to Mobility server
- CDMA integration
Converged Packet Gateway
Part of Evolved Packet Core

World’s Most Sophisticated Core
Converged Edge
Fixed & Mobile

Best of Both worlds
- LTE, GSM/WCDMA, CDMA
- Fixed MSER networks
Mobility + Fixed throughput
Software upgrades to SGSN/GGSN

Any to IP Transformation
**IP in Relation to Protocol Stack**

**Service/Protocol Stack**

- **Legacy SDH**
- **Legacy ATM**
- **Ethernet**
- **3G+ / 4G**
- **IP VPN**
- **Internet**
- **Video**
- **Voice**

**MPLS**
- + Packet mux
- + dynamic control plane
- + Fast restoration
- + OAM

**Ethernet**

**Optical Layer**

**Edge**
- Full IP/MPLS capable, from L2 to L7, user & session aware, foundation All-IP network

**CESR**
- Carrier-Ethernet Switch Routers, but support legacy technologies and advanced L2 capabilities

**LSR**
- Core routing and switching technology, price/performance pressured

**From dark fiber to DWDM equipment class**

**From dark fiber to DWDM equipment class**
Towards 50 Billion Connections

Today

Mobile

>4 billion subscribers
Personal services, Mobility, Interoperable
Subscriber scale optimized

Fixed

>400 million subscribers
Per household
Cost/bit optimized

Tomorrow

Full Service Broadband

50 billion connections
Personal, Mobility, Interoperable
Subscriber, device & cost/bit optimized

Mobile excellence proven for personalized services, interoperability and scale
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Mobile Broadband
A global success story

- 267 commercial HSPA networks
  - Ericsson: 127 (48%)
- >350 million WCDMA/HSPA subscribers
- 1470 HSPA devices
- 171 suppliers

Source: GSA – Global mobile Suppliers Association and Informa: May/June 2009
Cellular System Design

- Bandwidth
- Carrier frequency
- Power
- Cell sites

- Air interface
- Antennas
- Receivers
- Standards / proprietary
Air Interface

- Abstract
  - TDMA, CDMA, OFDM etc
  - Divy up resources of time, frequency, energy, space
  - Largely equivalent

- Reality
  - Finite complexity and real technology
  - Standards deviate from basic concept
  - Introduce specific limitations
  - Results in eco-system of specific techniques
  - Advantages in particular scenarios

- Different generations
  - Different technology ambitions
  - New techniques go with new systems
  - Unfair comparisons
WCDMA Background

- **WCDMA ("3G")**
  - Basics developed mid-90’s, standard ready -99
  - Circuit-switched voice
  - "ISDN-like" packet data (typically up to 384 kbit/s)

- **HSPA ("Turbo-3G")**
  - Packet-data improvement add-on to WCDMA
  - First version ~2002
  - Data rates up to 42 Mbit/s (downlink), 11 Mbit/s (uplink)

- **HSPA is an evolution of WCDMA**
  - Incorporating the basic principles from last session
WCDMA Basics – Spreading

Spreading

Wideband signal

Rapidly varying spreading code

De-spreading

Narrowband signal

Rapidly varying spreading code

One bit

Channel
HSPA Basics – Downlink and Uplink

- Similar principles for uplink and downlink
- But there are some fundamental differences

**Downlink**
- Power, codes
  - Tx power ‘centralized’
- Rate adaptation
  - (orthogonal ⇒ no near-far problem)
- Favorable conditions ⇒ high user data rate

**Uplink**
- Interference headroom
  - Tx power ‘distributed’
- Power control
  - (non-orthogonal ⇒ near-far problem)
- Favorable conditions ⇒ less interference
HSPA Evolution

- **HSPA – High-Speed Packet Access**
  - Evolution of 3G/WCDMA
  - Gradually improved performance in existing networks at a low additional cost
  - Data rates up to 42 Mbit/s in 5 MHz

- Evolution continues
  - Wider bandwidth, receiver improvements, protocol enhancements, ...

![Diagram showing HSPA evolution with data rates and standards](image-url)
Mobile System Evolution
Global Support

LTE is the Global standard for Next Generation – FDD and TDD
Spectrum Flexibility

- Spectrum flexibility ➔ operation in differently-sized spectrum allocations

- Support for paired and unpaired spectrum allocations

**FDD**
- **Paired spectrum**

**Half duplex FDD**
- **Reduced UE complexity**

**TDD**
- **Unpaired spectrum**

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23 MHz

**max 110 resource blocks**

**min 6 resource blocks**

**system bandwidth** $N_{RB}$

**cell search and broadcast of basic system information in the 6 center resource blocks**
LTE radio access

**Downlink: OFDM**
- Parallel transmission on large number of narrowband subcarriers

**Benefits:**
- Avoid own-cell interference
- Robust to time dispersion

**Main drawback**
- Power-amplifier efficiency

**Uplink: DFTS-OFDM**
- DFT-precoded OFDM

**TX signal has single-carrier properties**
- Improved power-amplifier efficiency
  - Improved battery life
  - Reduced PA cost
  - **Critical for uplink**

**Equalizer needed**
- Rx Complexity
  - **Not critical for uplink**
Downlink – OFDM with Cyclic Prefix

- Parallel transmission using a large number of narrowband “sub-carriers”
- “Multi-carrier” transmission
  - Typically implemented with FFT

![Diagram showing parallel transmission and cyclic prefix]

- Insertion of cyclic prefix prior to transmission
  - Improved robustness in time-dispersive channels – requires CP > delay spread
  - Spectral efficiency loss

![Diagram showing insertion of cyclic prefix]

$T_{CP} \approx 4.7 \mu s$

$T_{ECP} \approx 16.7 \mu s$
Cyclic Prefix – Simpler Receiver

- **Transmitter**
  - Symbol block
  - IFFT
  - S/P
  - add CP

- **Time dispersion**
  - Path 0: CP, data
  - Path 1: CP, data

- **Receiver**
  - S/P
  - FFT
  - Discard
Basic Principles

- Shared-channel transmission
  - Packet-data only
  - No CS support

- Channel-dependent scheduling
  - In time and frequency

- Hybrid-ARQ with soft combining
MIMO, ICIC, and MBSFN

- **Multi-antenna support**
  - *Integral part of LTE*
  - *All terminals support at least 2 Rx antennas*

- **ICIC**
  - *Inter-Cell Interference Coordination*
  - *To improve cell-edge performance*

- **MBSFN**
  - *Multicast-Broadcast Single-Frequency Network*
Downlink Physical Layer

CRC insertion (24 bits)

Rel 6 Turbo coding (with QPP interleaver)

Rate matching, redundancy version generation

Scrambling for inter-cell interference randomization

Modulation (QPSK, 16QAM, 64QAM)

Mapping to transmission layers (for multi-layer transmission)

Precoding (for multi-rank transmission)

Resource block mapping
Multi-antenna transmission techniques

- **Diversity** for improved system performance
- **Beam-forming** for improved coverage (less cells to cover a given area)
- **SDMA** for improved capacity (more users per cell)
- **Multi-layer transmission** ("MIMO") for higher data rates in a given bandwidth

The multi-antenna technique to use depends on what to achieve
### VoIP capacity

<table>
<thead>
<tr>
<th>Environment</th>
<th>LTE*</th>
<th>IMT-Advanced requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor Hot Spot</td>
<td>≈140</td>
<td>50</td>
</tr>
<tr>
<td>Urban Micro</td>
<td>≈80</td>
<td>40</td>
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<tr>
<td>Urban Macro</td>
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<td>40</td>
</tr>
<tr>
<td>High Speed</td>
<td>≈90</td>
<td>30</td>
</tr>
</tbody>
</table>

* According to 3GPP ITU submission / TR 36912 v9.0.0

**Very high VoIP capacity, substantially exceeding targets for IMT-Advanced**
LTE evolution towards LTE-Advanced

- LTE-Advanced is the next major step for LTE
  - Corresponding to LTE release 10
  - Direct evolution of the first release of LTE

- The 3GPP candidate for IMT-Advanced radio access