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TECHNOLOGY EVOLUTION OF MOBILE DEVICES

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SECTION 1: TRENDS
Standards Evolution (5 yr steps)

- **80’s**: Analog
- **1993**: Digital ex. GSM (8Kbps)
- **1998**: Basic Data ex. EDGE 1xRTT (50 Kbps)
- **2003**: Multimedia ex. WCDMA (300 Kbps)
- **2008**: High Speed Packet Data ex. HSPA (10 Mbps)
- **2012**: Wide Area Broadband ex. LTE WiMax (100 Mbps)
System/Service Evolution

Multimedia (ex. Audio/Video)

Data (ex. SMS, MMS, IMS, email)

Voice

Terminals  Radio Network  Servers/Gateways  Content

Convergence of 3 industries and proliferation of standards has increased complexity
Explosion of Standards

Telecom (ex. 3GPP)
- GSM
- GPRS
- EDGE
- WCDMA
- HSPA
- HSPA+
- LTE

Datacom
- TCP, IPv4, IPv6
- UDP, SIP
- SMS, MMS
- IMS (incl. VCC, DSC, MIH)...

Multimedia
- MP3, MP3 pro, AAC, AAC+, WMA, RA,
  - H.263, H.264,
- MPEG4, JPEG,
- WMV, RV, VC1,
- OpenGL 2.x, DRM..

Security
- AES, 3DES, SHA, MD5, RSA,
- FSA, DH, PKCS10, PKCS11, EAP,
- IKE, SSL, TLS, A5, A8, Snow..

Connectivity
- USB (FS, HS, OTG), BT, WLAN a/b/g/n, GPS, MobTV (DMB, ISDBT, DVBH, MediaFlo), Pictbridge,
- SGMII, SATA, SIM, SD, MS, ....
# High End Phone Feature Evolution

<table>
<thead>
<tr>
<th>Year</th>
<th>High end phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>High end phone</td>
</tr>
<tr>
<td></td>
<td>• narrowband CS voice</td>
</tr>
<tr>
<td></td>
<td>• 50-150 Kbps data (downlink)</td>
</tr>
<tr>
<td></td>
<td>• SMS, MMS</td>
</tr>
<tr>
<td></td>
<td>• Basic PIM</td>
</tr>
<tr>
<td></td>
<td>• 4K color display</td>
</tr>
<tr>
<td></td>
<td>• Primitive games</td>
</tr>
<tr>
<td></td>
<td>• 2 RF bands</td>
</tr>
<tr>
<td></td>
<td>• 100 MIP DSP</td>
</tr>
<tr>
<td></td>
<td>• 100 MIP CPU</td>
</tr>
<tr>
<td></td>
<td>• 8 Mbytes memory</td>
</tr>
<tr>
<td></td>
<td>• Basic Bluetooth, IR</td>
</tr>
<tr>
<td></td>
<td>• Keypad based UI</td>
</tr>
</tbody>
</table>

(Communication Device)

<table>
<thead>
<tr>
<th>Year</th>
<th>High end phone</th>
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</thead>
<tbody>
<tr>
<td>2008</td>
<td>High end phone</td>
</tr>
<tr>
<td></td>
<td>• wideband CS voice</td>
</tr>
<tr>
<td></td>
<td>• 7 Mbps data (downlink)</td>
</tr>
<tr>
<td></td>
<td>• 5 Mbps data (uplink)</td>
</tr>
<tr>
<td></td>
<td>• SMS, MMS, IMS</td>
</tr>
<tr>
<td></td>
<td>• Advanced PIM</td>
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<tr>
<td></td>
<td>• Multi format Audio &amp; Video</td>
</tr>
<tr>
<td></td>
<td>• TV out</td>
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<tr>
<td></td>
<td>• Basic browser, Basic games (2D)</td>
</tr>
<tr>
<td></td>
<td>• DRM</td>
</tr>
<tr>
<td></td>
<td>• FOTA</td>
</tr>
<tr>
<td></td>
<td>• 5-8 MP camera</td>
</tr>
<tr>
<td></td>
<td>• 16M color display</td>
</tr>
<tr>
<td></td>
<td>• 10 RF bands</td>
</tr>
<tr>
<td></td>
<td>• 500 MIP DSP, 500 MIP CPU</td>
</tr>
<tr>
<td></td>
<td>• 8 GBytes memory</td>
</tr>
<tr>
<td></td>
<td>• Bluetooth, WLAN, GPS, USB HS</td>
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<tr>
<td></td>
<td>• Sensor based UI</td>
</tr>
</tbody>
</table>

(Multi Media Device)

<table>
<thead>
<tr>
<th>Year</th>
<th>High end phone</th>
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</thead>
<tbody>
<tr>
<td>2012</td>
<td>High end phone</td>
</tr>
<tr>
<td></td>
<td>• wideband VoIP</td>
</tr>
<tr>
<td></td>
<td>• 100 Mbps data (up/down)</td>
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<tr>
<td></td>
<td>• Integrated messaging/mail</td>
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<tr>
<td></td>
<td>• Integrated PIM, real time sync/presence/notification</td>
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<tr>
<td></td>
<td>• Multi format Audio &amp; Video &amp; full 3D gaming</td>
</tr>
<tr>
<td></td>
<td>• Full browser</td>
</tr>
<tr>
<td></td>
<td>• DRM + e-commerce</td>
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<td></td>
<td>• FOTD A</td>
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<tr>
<td></td>
<td>• 8-16 MP camera</td>
</tr>
<tr>
<td></td>
<td>• 24M color display</td>
</tr>
<tr>
<td></td>
<td>• Aux display connect (HDMI)</td>
</tr>
<tr>
<td></td>
<td>• Universal RF bands</td>
</tr>
<tr>
<td></td>
<td>• 3GHz Multi-cores</td>
</tr>
<tr>
<td></td>
<td>• 50 GBytes memory</td>
</tr>
<tr>
<td></td>
<td>• BT, WLAN, GPS, USB 3.0</td>
</tr>
<tr>
<td></td>
<td>• Context sensitive sensor based UI</td>
</tr>
<tr>
<td></td>
<td>• Personal server</td>
</tr>
</tbody>
</table>

(True Personal Server)
SECTION 2: IMPLICATIONS
Implications

• Transformation of Mobile Phone Manufacturers (OEMs)
• Emergence of Platform Players
• Exponential increasing in software, testing & interoperability
• Radio complexity
• Growth in computation power & memory
• Architecture Changes
• Consolidation
Transformation of OEMs

Focus (Then)
- Modem
- Manufacturing
- Technology
- Performance
- Price

Focus (Now)
- Brand
- Channels
- Industrial Design
- Usability
- Services/Applications
Emergence of Platform Players

Core SW platform (Telecom, Datacom, Security, Multimedia codecs/file formats, Connectivity enablers)

Applications

User Interface

Has cut down phone development to 6 months from 18 months
Software Complexity

1998
1 million lines of code
Single RTOS
Mainly Modem
Few Applications
Simple UI
Little User Data

2012
10-15 millions lines of code
Multiple processors
Multiple OS/Hypervisors
Multiple Modems
Complex graphical UIs
Large User data
Over the air download of features/functions
Increase in Test

Exponential increase in testing to ensure end-to-end interoperability

Typical phone launch requires about 50,000 test cases

Tests: IOT, Regulatory, Signaling, Conformance, System, Use Case/Functional, User Interface, Key Performance Indicators
Radio Proliferation

- 2G : 4 bands
- 3G : 10 bands
- LTE, WiMax: adds a band
- WLAN
- GPS
- BT
- Mobile TV (DMB, DVB-H, MediaFlo, ISDB-T) – multiple bands

- Different bandwidths

Antenna’s and Filters take space (area and volume)
Filters and switches (connection to antenna) cause loss (power)
Obvious Challenge is Power Consumption
Hardware Architecture

Power Management/Audio
RF
Baseband
BT
WLAN
GPS
Memory

Complex Power Management
GPS
WLAN
BT/FM
Cellular Modem
Application Processor (server)
Memory
Sensors
Typical Software Structures
Consolidation

Operators (10 have 50% market share)

Infrastructure Providers (5 control 75% of market)

Phone OEMs (7 control > 90% market)

Platform Players (2 major and 1 niche)

Process Technology (3 major players)
SECTION 3: CHALLENGES & OBSERVATIONS
Challenges

- Power Consumption (1 day use on a 750 mAH battery)
- Size (50 cc is convenient to carry)
- Cost (consumer devices ASP drop 20% per year)
- Rapid enablement of service offering/customization
- Usability
Power Consumption

- Battery technology has shown marginal volumetric or gravimetric capacity gain

- Need to look at all aspects of power conservation

- **Usage**
  
  *Example:*
  - 2 hours talk (150 maH)
  - 1 hour data transfer – Browse/mail (150 maH)
  - 8 hours music (50 ma)
  - 3 hours video or gaming (300 maH)
  - hours standby (15 maH)
Power Consumption

- **System**: Ex. Good interface design, sensors ...

- **Software**: Ex. Smart OS (scheduling), Algorithms, Data Movement, Fast Switching..

- **HW Architecture**: Ex. Task specific cores, Novel converters....

- **Circuit**: Ex. Multiple Vt, DVFS, DPTC, SRPG ....

- **Process**: Ex. 32 nm high K, CMOS radios....
Data Speed & Power

Processing
- 30X speed + shorter transmission time interval (1 ms)
- Computation load of PHY and MAC layer processing is equivalent to 15-20Bips
- Heterogeneous processors offer one solution
  - Example: Time based processing, efficient multi thread handling capability

Uplink
- Higher level linear modulation needed – Peak-Average Power ratio problem
  - GSM PAPR = 0 dB
  - WCDMA (HSUPA) PAPR = 3 dB
  - LTE PAPR = 6 dB
  - WiMAX PAPR = 8 dB
- Broad band linearization techniques needed
RF Power, Size, Cost

- Multiple bands means more filters and complex front-end network
- Can save size and cost by eliminating filters
- This causes higher linearity requirements on radio and data converters
  - Higher linearity translates to increase in current (power)
- Bandwidth increase further complicates the problem (sampling rate)
- If we can eliminate filters we can use eliminate concept of separate PAs
- LVDS based high speed serial interfaces

\[ I = \frac{P_o \times L}{(\text{Eff.} \times V)} \]
Application Processing/Power

- Audio, Video, Graphics, Imaging, Security all have different characteristics
- Dedicated accelerators are typically used (speed-power trade off)
- Bus structure or serving node should not bottleneck
- Restrict moving data across large domains or frequent memory access (local memory and local bus)
- Smart scheduling via OS will be a key differentiator
- Adequate processing power for full OS
Comments on Size

- Size is typically dominated by Display, Battery and Antennas

- Size can be minimized
  - by removing filters and number of PAs
  - reducing frequency of operation (die size) on sub-systems
  - packaging (examples)
    - Distributed Chip Package
    - Wafer Level Packaging
    - Integrated passives
    - Package on package (especially, fan-in POP)
Software Structure for broad based Service Offering

API

App Set 1/OS1

App Set 2/OS2

Hypervisor

Multiple Radios and Multiple Cores

Tools (compile, profile, link, debug) for these architectures are underdeveloped. Security becomes a challenge.
Usability

▪ Sensors offer improved usability
  ▫ Capacitive touch screen displays
  ▫ Haptics
  ▫ Dual and triple axis MEMS based accelerometers and Gyros
  ▫ Dead reckoning and GPS augmentation

▪ Context sensitive user interface
  ▫ Ex. buttons & controls change for audio, camera, video, gaming

▪ Multiple microphones and speakers (sound effects and noise cancellation)

▪ Projection on larger screen devices
Summary

• There will be almost 4 billion mobile phone subscribers by 2012

• Fastest growing segment is expected to be Smartphones and MID

• Mobile phones will become personal media/information devices with seamless connectivity

• Data speeds and applications drive enormous processing capability needs

• Wide area broad band will enable a lot of new applications

• Power conservation, testing and security are the biggest challenges