Building Reconfigurable Base Stations

Alan Gatherer
CTO Wireless Infrastructure
Texas Instruments
Agenda

- Why we love reconfiguration
- Degrees of reconfiguration
- Where are we today?
- Software Defined Radio
- Reconfiguration architecture options
- Summary
Agenda

◆ Why we love reconfiguration
  ◆ Degrees of reconfiguration
  ◆ Where are we today?
  ◆ Software Defined Radio
  ◆ Reconfiguration architecture options
  ◆ Summary
GSM base stations showed over 16% and 13% growth respectively in 2003 and 2004.
By some accounts, the GSM transceiver shipments in these two years grew over 50%.
Shipping into both new deployments as well as existing base stations.

Source: “The Numbers Add Up with GSM and WCDMA”, [http://www.3g.co.uk](http://www.3g.co.uk)
2G is Diehard. Is 3G Diehard II?

2G (GSM)

- 2
- Frequency hopping
- Channel reuse
- GPRS
- Vocoder improvements
- SAIC
- HARQ
- EDGE

3G (WCDMA)

- 3
- HSDPA
- HSUPA
- TxDiversity
- MIMO
- ???

“We’ll use our GSM equipment ‘til it rusts....”
Rush to Deploy

- Many competing technologies
  - WCDMA, EVDO, 802.16, TD-SCDMA

- WCDMA deployed much earlier in its development cycle than GSM

- WCDMA / EV-DO continue to develop
  - Competition with each other in Japan
  - Competition with the promise of 802.16
WCDMA (R99) vs GPRS (R97)
Change Requests / Qtr: June ’97 – Dec 04

Source: Agilent Technologies

Source: ETSI CR Database 11 Jan 2005
No Convergence in 3G

- cdmaOne IS-95-A
  - Voice
  - 14.4 kbps
  - CSD & PD

- cdmaOne IS-95-B
  - Voice
  - 64 kbps Packet

- CDMA2000 1X
  - High Capacity Voice
  - 153 kbps Packet
  - Rel. A-307 kbps

- CDMA2000 1xEV-DO
  - 2.4 Mbps Packet

- CDMA2000 1xEV-DV
  - >2.4 Mbps Packet
  - Higher Cap Voice

- TDMA IS-136
  - Voice
  - 9.6 kbps CSD

- GSM
  - Voice
  - 9.6 kbps CSD

- GSM GPRS
  - 114 kbps Packet

- W-CDMA
  - Higher Capacity Voice
  - 2 Mbps Packet

- W-CDMA HSDPA
  - >2 Mbps Packet
  - Higher Cap Voice

- CDMA2000 1xEV-DO

- EDGE

- TD-SCDMA

- 802.16 ??

1999 2000 2001 2002 2003 2004 2005 2006

GSM: Global System for Mobile Communications
CDMA: Code Division Multiple Access
TDMA: Time Division Multiple Access
GPRS: General Packet Radio System
HSDPA: High Speed Downlink Packet Access
EDGE: Enhanced Data rates for GSM Evolution
EV: Evolution; DV: Data and Voice; DO: Data Optimized
W-CDMA: Wideband CDMA: General Packet Radio System

Technology for Innovators™

Texas Instruments
We Like to Make Money!

- **Total Cost**
  - FPGA
  - DSP
  - ASIC

- **Fixed Cost**
  - ASIC
  - DSP
  - FPGA

**NB:**
Need to watch:
- Power
- Form factor

*Technology for Innovators*
Caveats For Cost Per Unit

- **Power**
  - Continues to be critical to base station designs. Base stations are often in enclosed spaces and experience wide temperature variations. These systems need to operate with high reliability for years.
  - Means some reconfigurable devices. Even some DSPs fail the basic power limit for a hot spot.
  - Low power efficiency of power amplifiers has forced the industry to focus on Power Amplifier (PA) efficiency and not flexibility.

- **Cost**
  - There continues to be significant cost pressure on base station equipment. The cost of 3G systems is dropping rapidly. WCDMA has already fallen below GSM in cost per channel.

- **Complexity**

- **Development time**
PA is consistently the high cost item, so focus in PA is cost reduction, not reconfiguration.
Complexity: Data is Harder Than Voice

Voice modem resource scheduling
- Static for the life of the user
- Similar across users
- No fragmentation
- Deterministic scheduling

Data modem resource scheduling
- Dynamic resource requirement
- Widely varying resources
- Fragmentation possible
- Dynamic scheduling
- Adaptive modulation, HARQ
Development Time

- **Maximum Available Revenue**
- **Total Lost Revenue Due to Delayed Entry**
- **Market Rise**
- **Market Fall**
- **Time to Market**
- **Ramp to Production**
- **Total Market Window**

- **Revenue**
- **Time**
ASIC Industry Design Starts Declining

Source: iSuppli 2Q04
FPGA Gaining in Wired/Industrial

Source: iSuppli 3Q04
Cost of ASIC Affecting Design Starts

Example: Saving 25% of Unit Cost with ASIC

- Wireless Computer Consumer
- Wired Access/Basestation
- Wired Datacom
- Wired Telecom

<table>
<thead>
<tr>
<th>Units Shipped to Payback Investment</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>10KU</td>
<td>$10M</td>
</tr>
<tr>
<td>100KU</td>
<td>$10M</td>
</tr>
<tr>
<td>1,000KU</td>
<td>$10M</td>
</tr>
<tr>
<td>10,000KU</td>
<td>$10M</td>
</tr>
</tbody>
</table>

Unit Cost of ASIC

- $10
- $100
- $1,000
Agenda

- Why we love reconfiguration
- Degrees of reconfiguration
- Where are we today?
- Software Defined Radio
- Reconfiguration architecture options
- Summary
What is Reconfigurable?

- Common base station
- Common modem cards
- Common footprint
- Common chassis
- Common programming platform
- Common elements

MOST

LEAST
Common Base Station

- On-the-fly reconfiguration of base stations
  - Still very expensive
  - Carriers generally don’t need this level of flexibility
  - Some rural carriers see value when roaming as the dominant revenue source
  - Hoteling?
- Vanu
  - Uses off the shelf servers
  - Cost reduction for small quantities as off-the-shelf DSP cards tend to cost more (but wait for ATCA), even though DSPs tend to be cheaper and lower power per function
- Lyrtech
  - DSP/FPGA board
  - “Universal Base Station” system, using flexcell™ and SignalMaster software-design radio (SDR) platforms
  - multi-band (AMPS, GSM, WCDMA, VHF and 802.11)
- ACT
  - Produced a generic DSP / FPGA board for multi-standard
Common Base Station Issues

- Cost
- RF and Analog
- Cell planning for a reconfigurable network?
  - Cell planning and site acquisition is a major issue
  - Cell planning even occurs for WLAN in the enterprise
- Backhaul network differences
  - IP?
  - What about mobility
- An idea whose time is yet to come
  - Frequency agile standards such as 802.22 might have some reconfigurable elements to them
Common Modem Cards

- Much more likely in the mid term
- 64 WCDMA may imply 72.6 GSM (I guessed)
  - This isn’t a useful number
  - Still, if you have a new standard that isn’t shipping in volume......
- Inventory savings
- Reduced NRE

Apples to oranges 1 lb apples to 1 kilo apples
A single board for multiple standards with a few missing components that define frequency range and bandwidth.
Common Chassis

◆ Use the same rack and backplane
  ◆ e.g., CPRI, OBSAI, ATCA

◆ Use the same controller cards
  ◆ Especially with a common network termination
  ◆ e.g., OBSAI

◆ Use the same power supply and clock distribution cards
OBSAI, CPRI, ATCA

OBSAI (open base station architecture initiative)
- Defines the whole base station mechanicals and electric interfaces, including the control and transport cards. Some software messaging is also defined.

CPRI (common public radio interface)
- Focuses on the baseband to analog card interface.

ATCA (Advanced Telecom Computing Architecture)
- Optimized for telecoms transport.
- Probably too expensive for radio baseband.
- uATCA may be more suitable for radio.
- A great prototyping platform at least, using RapidIO as the backplane for scalability.
Common Platform

- Make the modem look as similar as possible at the software level across different standards
- Hardware abstraction
- Common APIs
- Reuse of common software blocks
- Same software tooling allows engineers to move between projects
- This is what SDR really is for wireless infrastructure!!
Agenda

- Why we love reconfiguration
- Degrees of reconfiguration
- Where are we today?
- Software Defined Radio
- Reconfiguration architecture options
- Summary
Example: WCDMA

- Preamble Detect
- Search
- Control Despread
- Data Despread

- Post Process
- Channel est
- MRC

- Messaging Resource Allocation & Control
- Symbol Rate Processing

- Needs some acceleration. Often ASIC
- Maybe software
- Software
Digital Baseband Trends

- WCDMA is the most complex
- CDMA chip rate generally needs some sort of acceleration
- EDGE / GSM, TDSCDMA, 802.16 can be done in software
- More data (and less voice) lead to more software-oriented solutions
  - Less chip rate processing, more symbol rate processing
  - HARQ and MAC functions now on the modem
Wireless Infrastructure

Digital Up and Down Convert

- Specialized DUC/DDC chips on the market that are parameterizable
- Big OEMs may do their own ASIC
- FPGAs also used
- Predistortion and crest factor reduction are now being used, but focus is on cost – not reconfiguration
Trends From Analog to Digital

- VCO are typically fixed
- SAWs are fixed
- Zero IF to remove SAWs
  - Is used on Tx
  - Rare in Rx for BTS due to stress on analog components
  - Benefit: Carrier selection at BB
- PA and LNA are fixed in center frequency and bandwidth
Agenda

- Why we love reconfiguration
- Degrees of reconfiguration
- Where are we today?
- **Software Defined Radio**
- Reconfiguration architecture options
- Summary
SDR vs Reconfigurable Base Station

- Software defined doesn’t imply reconfigurable

- SDR is an object oriented philosophy of system design and may or may not imply reconfigurability:
  - Reduces NRE. Allows smooth migration to next platform and lower time to market
  - SDR gives hardware abstraction
  - SDR allows software elements to be plug and play
  - SDR enables reconfigurability in many cases

- Reconfigurable implies the design takes account of multiple radio standards
The CORBA Gatekeeper

- Operating System
- Network Stacks & Serial Interface Services
- Board Support Package (Bus Layer)

- CORBA ORB & Services (middleware)
- CF Services & Applications

- Non-CORBA Modem Components
- Modem Adapter
- Link, Network Components
- Security Adapter
- Security Components

- Applications
  - Core Framework (CF)
  - Commercial Off-the-Shelf (COTS)

- OE

- Non-CORBA I/O Components
- Non-CORBA Security Components

- Black Hardware Bus
- Red Hardware Bus

Software “bus” controls all transactions

Core Framework IDL ("Logical Software Bus" via CORBA)
How the ORB Works

- All components, *whether software or hardware*, have an Applications Programming Interface (API) that allows the “client” application to access them in a regular, object-oriented way via the “logical software bus”
  - In this manner the objects can be added and removed easily
- At the heart of this easy addition and subtraction is the Common Object Request Broker Architecture (CORBA).
  - Communication between objects is managed by the Object Request Broker (ORB)
How the ORB Works

- The objects do not have to be aware of each other, only the ORB.
- In order to be recognized by the system, each object has a domain profile.
- The ORB, along with the core framework (CF) that defines the interfaces is a “middleware”:
  - Middleware is common in base station modems today.
  - But not usually this complex.
Agenda

- Why we love reconfiguration
- Degrees of reconfiguration
- Where are we today?
- Software Defined Radio
- Reconfiguration architecture options
- Summary
The Dependable Programmable Processor

**DSP or GPP**
- Differences are somewhat subtle these days

**DSPs tend to be . . .**
- Focused on embedded market
- Lower power per function
- Lower cost per function
- Focused on arithmetic functions that also require control

**GPPs tend to be . . .**
- Focused on computing market
- Focused on decision making
- Good for housekeeping and control
The Dependable Programmable Processor

- A really good platform for the type of OO C, C++, SDR programming that everybody does
- "Mild" multi-core is appearing
  - e.g., TNET3010
  - Less than 10 cores
  - Usually aimed at DSP farm applications
    - e.g., Transcoding, RNC, GGSN
- Can be light on MIPs due to limited parallelism
Good Ol’ FPGA

- Large amounts of parallelism
- Programming style like RTL
  - Needs support to work in a SDR environment
- Traditionally used for glue logic
- Embedded multipliers and cores are moving FPGAs into DSP
- Power and Cost have been traditional impediments
“Reconfigurable” Processors

- A catch all for anyone who isn't GPP/DSP or FPGA
  - e.g., Morpho, Freescale, Picochip, PACT
- Usually have parallelism between DSP and FPGA
- Claim to be easy to program but this is far from clear
  - Usually involve a mixture of C code and RTL like structured coding
  - Debug can be difficult
  - Not suitable for control code
"Reconfigurable" Processors

Fall into 2 categories
- Parallel array of programmable elements
- Parallel array of ALUs

Issues
- Local connectivity
- Utilization of resources in real applications
Real time algorithms need a device which effectively handles both math intensive functions and control code functionality!!

DSP is best solution for cost-effective, high-performance signal processing problems.
DSP Block Diagram: TMS320TCI6482

C64x+ Core
- WI INST.
- Chip rate
- L1P (32k)
- L1D (32K)

L2 (2MBytes)

EDMA 3.0 (Switch Fabric)
- GPIO
- I2C
- PLLs
- Timers
- Others
- Boot
- VCP2
- TCP2

VLYNQ
- McBSP
- Gigabit Ethernet
- UTOPIA
- HPI PCI-66
- Serial RapidIO
- DDR2 EMIF
- EMIF 64

Technology for Innovators™
Texas Instruments
Agenda

- Why we love reconfiguration
- Degrees of reconfiguration
- Where are we today?
- Software Defined Radio
- Reconfiguration architecture options

- Summary
Why/What is Reconfigurable

- Reconfiguration being pushed by:
  - Standards evolution
  - Complexity
  - Cost
  - NRE and time to market

- *Not* by multimode modems

- Reconfiguration comes in many forms – from software to common mechanicals
Progress

♦ SDR is an OO approach to complex system development

♦ It enables reconfiguration rather than being driven by it

♦ Most architecture progress is in DBB:
  ♦ More DSP / GPP MHz
  ♦ More DSP focused FPGA
  ♦ New reconfigurable architectures