NORTEL NETWORKS

Technologies & Systems for Fourth Generation Mobile Wireless Systems

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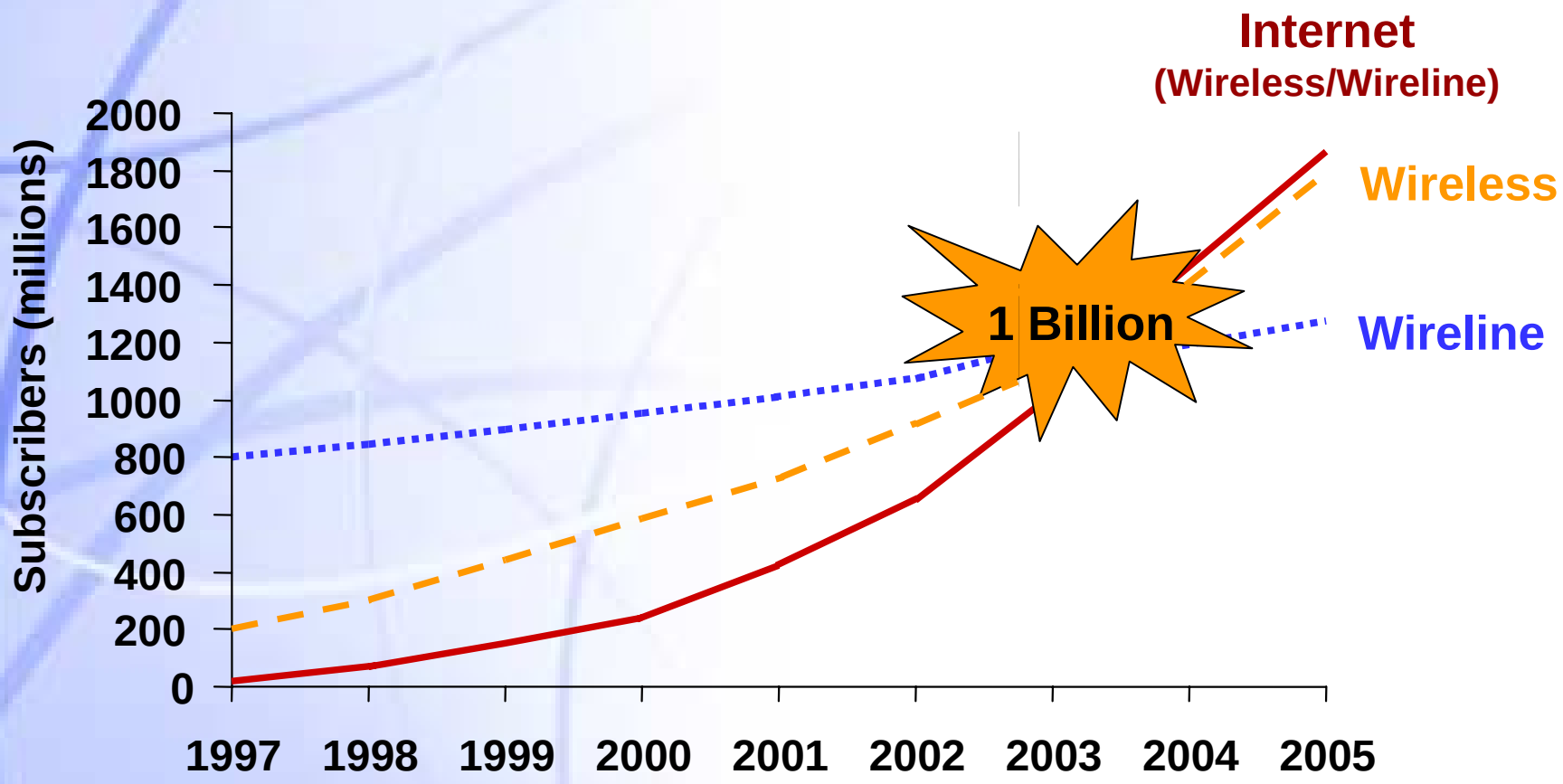
September 20, 2000

Outline

- ***Markets and Applications***
- ***Network Evolution***
- ***Radio Access Evolution***
- ***Summary***

Markets and Applications

Internet Growth Fueled by Wireless

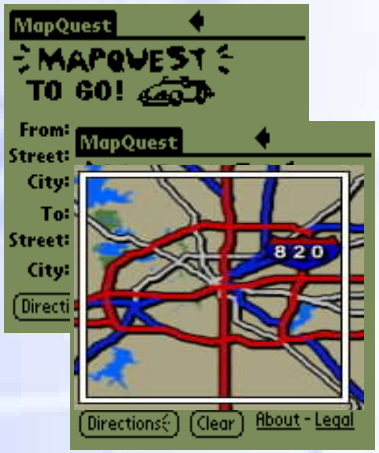


Explosive traffic growth and service shift in wireless :
Data will dominate wireless traffic (70% vs 30% for voice in 2005)

Source: Nortel Networks

Wireless Internet: Consumer Applications

Information / Entertainment
- News / Sports
- Financial
- Directory Enquiries
- Yellow Pages



Mobile Messaging
- SMS
- Internet email
- Unified Messaging

e-Commerce
- On-line banking
- Intelligent Brokering
- Gaming / Gambling
- Interactive Shopping
- e-Cash
- Music Download
- Electronic ticketing

Travel / Location
- Traffic info
- Navigation Services
- Location Services
- Time Tables
- Travel schedule updates

Internet Access
- Web Browsing
- Portals, VHE

Wireless Internet: Business Applications

Corporate

Mobile Messaging
- SMS
- email
- Unified Messaging

Mobile Office
- corporate e-mail
- Intranet Browsing
- file transfer

Corporate GroupWare
- Corporate Info / news
- Travel / Directory Service
- PIM synchronisation

Tele-presence
- Collaborative working e.g. NetMeeting

Telemetry

Remote Monitoring & Control
- vending machines
- ticket machines
- automatic metering
- video surveillance
- E-POS

Traffic Telematics
- Parking & tolls
- vehicle tracking
- route guidance

Field Service

Real-time Business Process Support
- dispatch
- fleet management
- emergency services
- utilities
- field service management
- sales force / inventory management

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The Mobility Paradigm is Shifting

3G Will Offer...

- variable bandwidth
- network efficiencies
- desktop/multimedia *with* mobility
- service personalization

Today's Mobility Users Want To...

- personalize their service
- access high-speed data
- take their desktop with them
- use multi-media services

Today's IP Services Are...

- tied to home or office
- high bandwidth
- packet switched

Today's Mobility Services Are...

- voice-centric
- generic
- low-speed data only
- fixed bandwidth

Wireless Internet *is* the new Paradigm!

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3G and The Wireless Internet

2G: Circuit

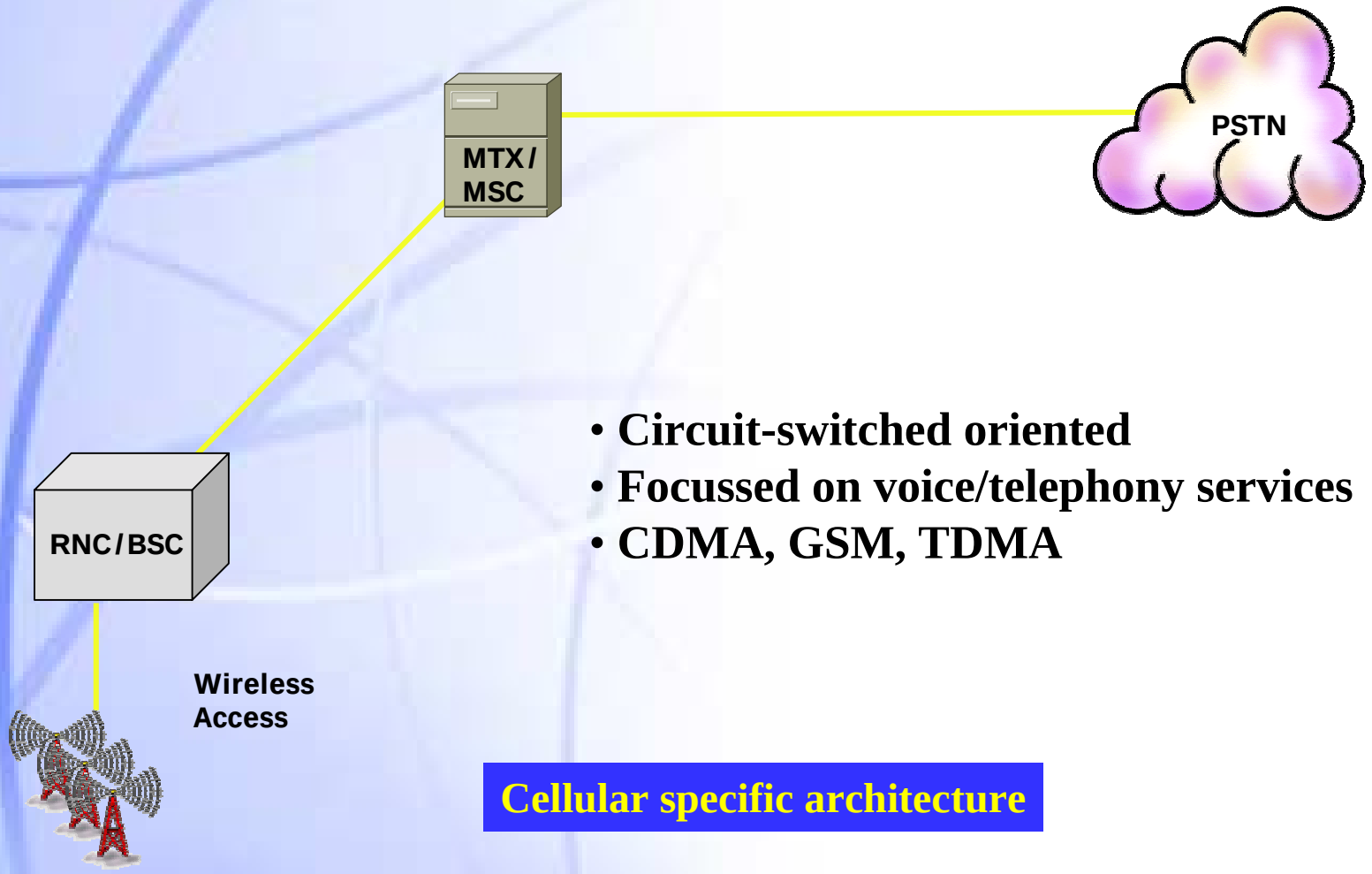
- Channelized
- Connection-oriented services
- Fixed bandwidth
- Connection-oriented networks
- Proprietary network infrastructure
- Closed service environment

3G: Packet

3G Enables the Wireless Internet

Network Evolution

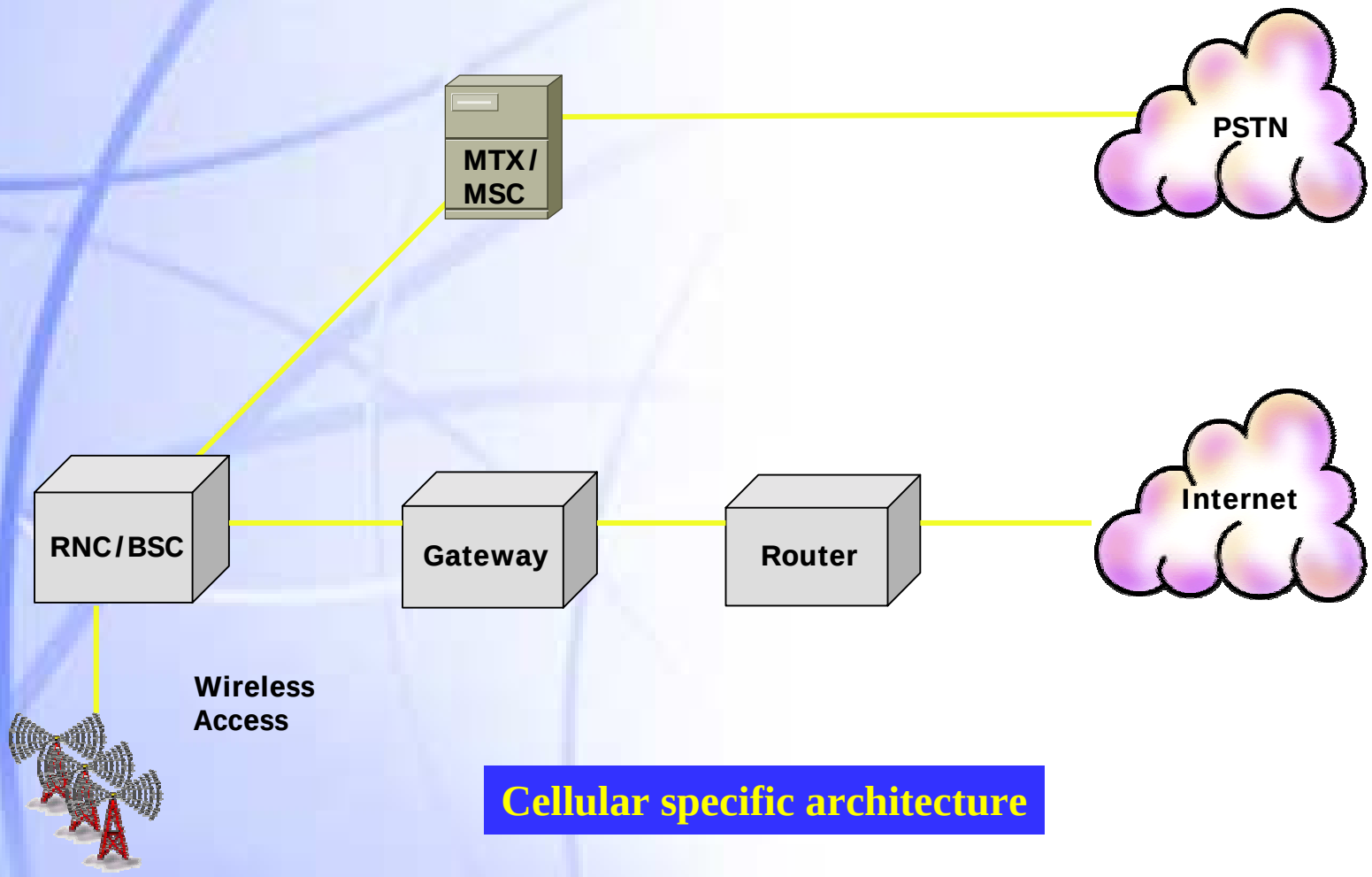
Current 2G Cellular Architecture



- Circuit-switched oriented
- Focussed on voice/telephony services
- CDMA, GSM, TDMA

Cellular specific architecture

Cellular Architecture With Data Overlay

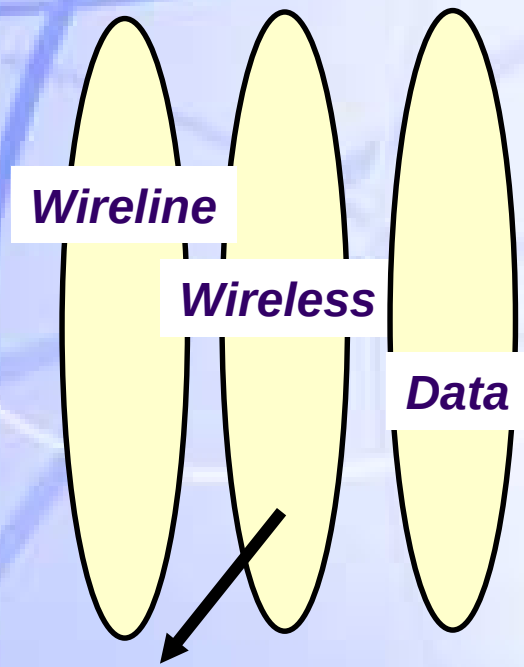


Cellular specific architecture

Network Evolution

Today

Separate networks for each function

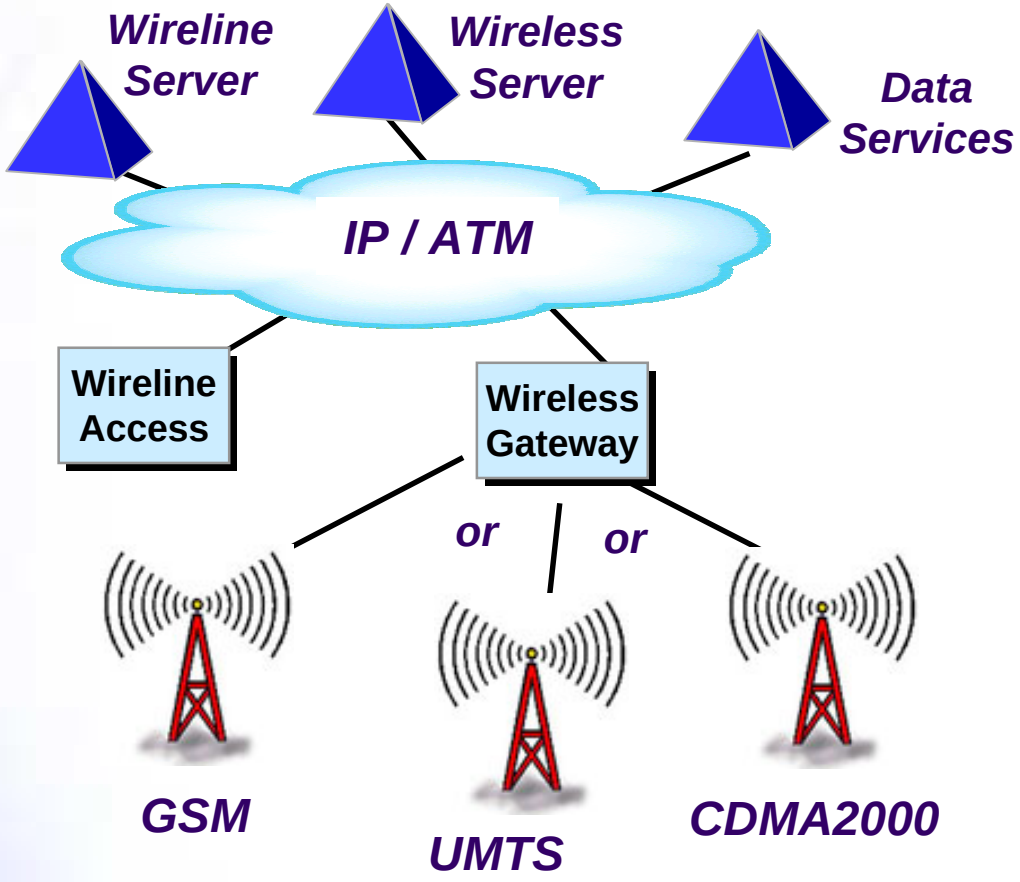


Wireless Networks (CDMA, GSM, TDMA)

- Circuit-switched oriented
- Cellular-specific
- Focussed on voice/telephony services

Unified Networks

Single distributed network, multiple services, packet architecture



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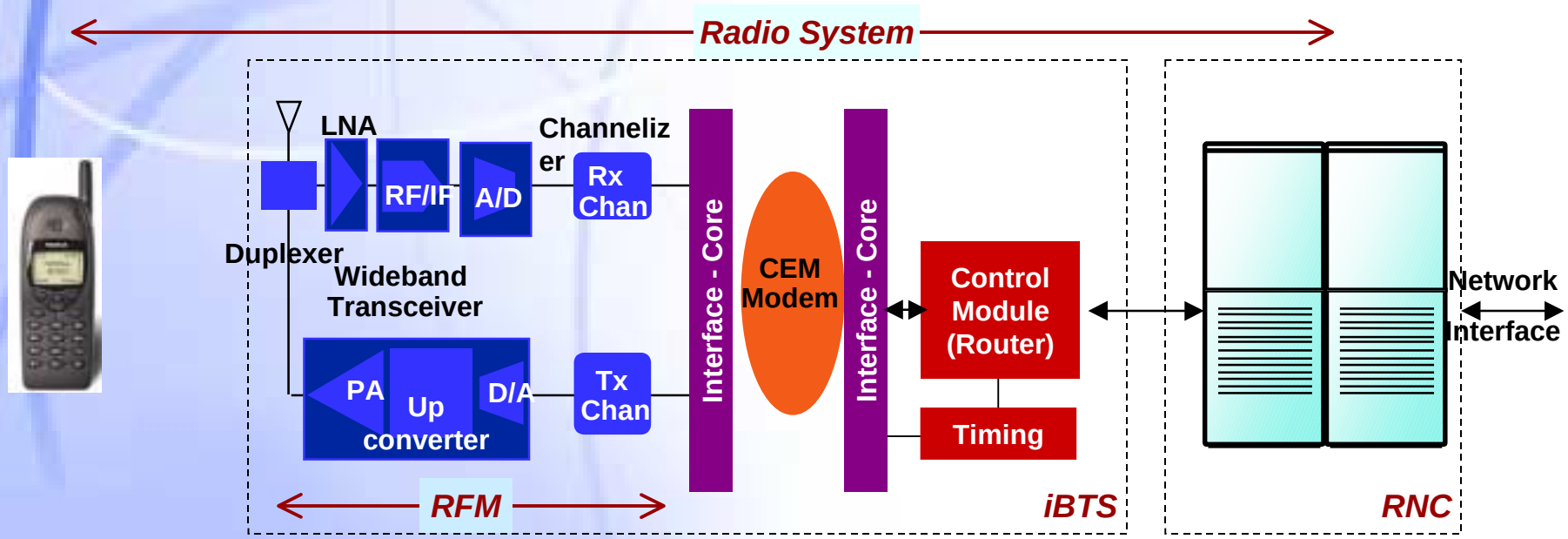
Radio Access Evolution

Roadmap of Enabling Radio Technologies

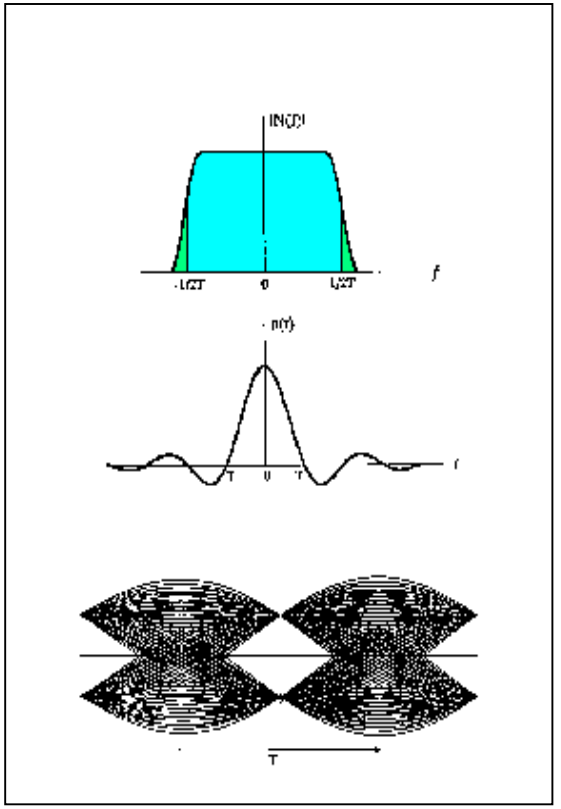
- Wideband Transceiver
- Advanced PAs
- RF Transceivers
- Advanced Modems
- Multi User Detection

- Multi Beam Antenna Systems
- Space Time Coding
- Radio Resource Management & Layer 2



Advanced Modems

- **Numerical methods for optimum transmission and recovery of payload bits**
  - **generate “optimum” waveforms**
  - **recover waveform degraded by noise and interference**
- **Architectures using DSP, ASIC, re-configurable silicon**
  - **capable of multiple standards (e.g. IS-95, 1xRTT, HDR, UMTS DS)**
  - **cost-effective, flexible, scalable channel unit design**
- **System performance differentiator**
  - **capacity, range, errors, costs, TTM..**



Beta=0.22 Raised Cosine Channel Filter

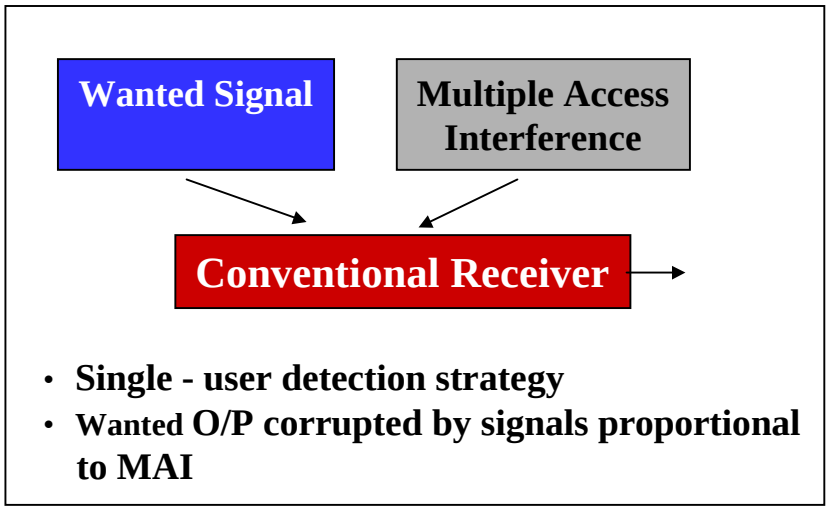
Architecture enables future features for improved performance e.g. Multibeam, Multi-User Detection, Space Time Coding, Adaptive Modulation etc.

Multi-User Detection (MUD)

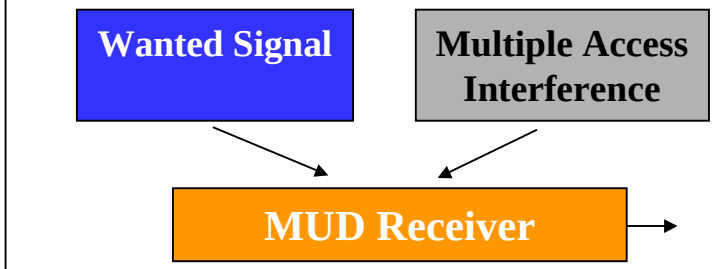
- **Joint detection of uplink users in a cell or sector to reduce multiple access interference (MAI) in order to:**
  - **increase capacity, especially in presence of high data rate user**
  - **improve robustness in the presence of power control error,**
  - **minimize terminal Tx power**

  while maintaining reasonable/acceptable complexity.
- **Established track record in co-channel interference cancellation, with features rolled out in GSM, EDGE and IS-136 product**

Current program includes prototyping a Soft Iterative Multi-User Detector (SIMUD) scheme



- **Single - user detection strategy**
- **Wanted O/P corrupted by signals proportional to MAI**



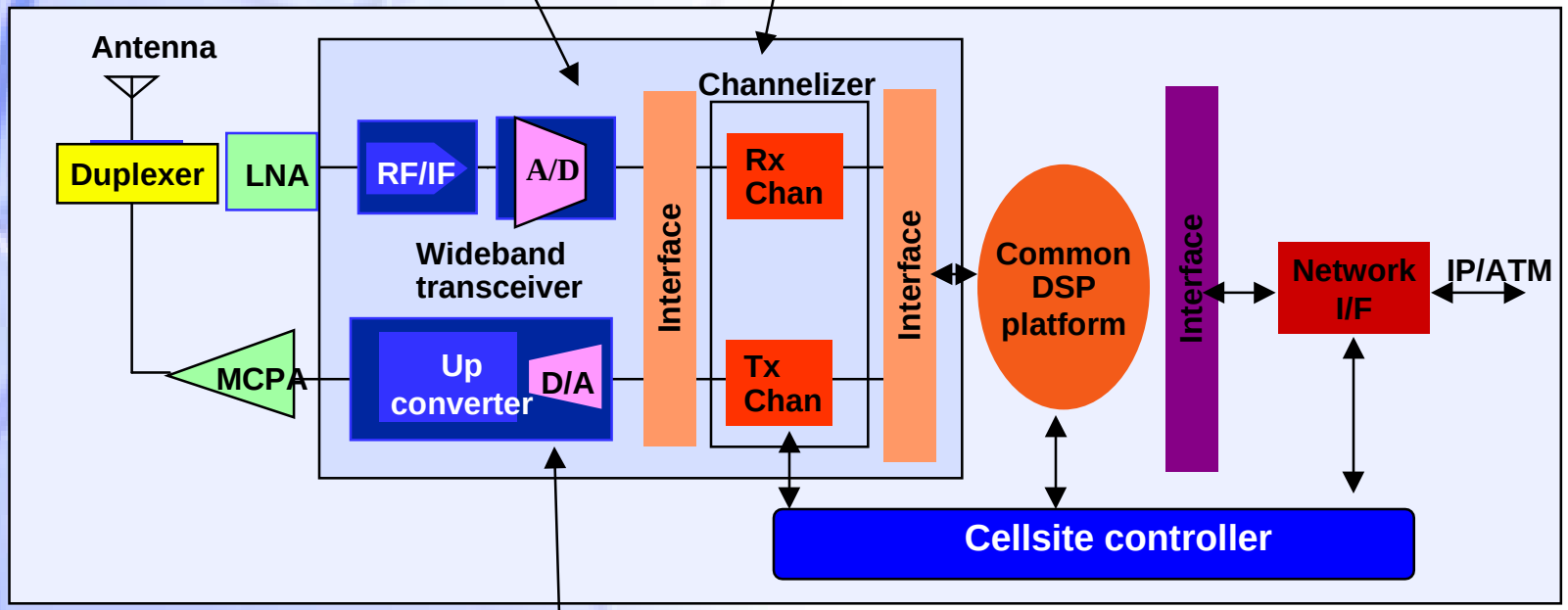
- **Multi - user detection strategy**
- **Joint detection suppresses/cancels MAI in Rx O/P**

Wideband Software Radio

- Common WB technology for multiple radio platforms
- Time -To-Market

- 14 bit @ 80MHz ADC
  - sufficient to meeting 15MHz wideband multi carrier IS136, IS95, UMTS single tone de-sensitivity spec
- 16 bit ADC will meet GSM spec

- Multi-mode (IS95/1xRTT/3XRTT, UMTS) Channelizer design with common clock rate
- Power measurement & noise injection to control cell range
- PPR & AGC
  - *saves ~3 dB peak-mean power for PA savings*



- 14 bit @65MHz
  - 10 MHz is marginally achievable for IS95 spec (-55dBc)
  - 16 bit (available 1Q01) is required for IS136 (-60dBc)

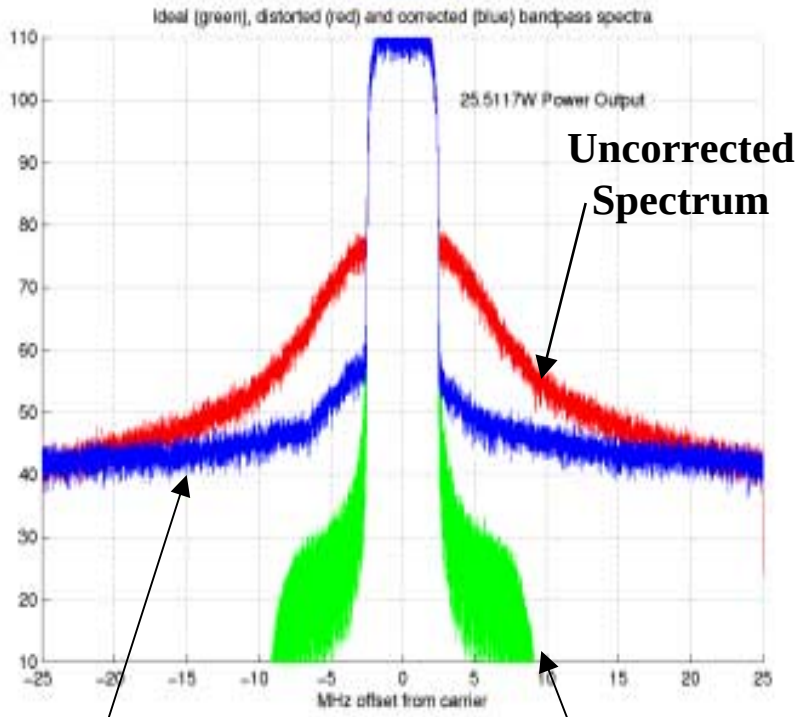
Ultra Linear Power Amplifiers

- **PAs are potentially 50 - 70% of future base station cost**
  - Without innovative PA design and channelizer PA power savings
- **Aim is to develop technologies for dramatically lower cost**
- **Digital Pre-distortion compensates for PA non-linearities**
  - Enabled by accurate modelling of LDMOS power devices
  - “RF” Feed-Forward is replaced by “Digital Pre-Distortion”
  - DSP-based algorithms for adaptive compensation
  - “Digital” based correction implementation leads to lower cost & high efficiency
- **Program**
  - System simulation, analysis and 5MHz (1 Channel) proof-of concept completed
  - 15 MHz (3 Channel) Bandwidth proof-of-concept available in Sept

Proof-of-Concept UMTS Power Amplifiers

- System parameters have been determined to meet a >-55 dBc ACP target
  - 3 Ch UMTS specifications call for ~50dBC, (-13dBm/MHz) thus allowing for margin
- Digital system parameters used
  - 160 MHz clock speed, 10-bit ADCs and 12-bit DACs for 15 MHz prototype
- Adaptation algorithm converges after power on
- About 8 dB back-off from P_{1dB} required in the PA Module
  - giving approximate PA efficiency η=12%

Simulated Performance

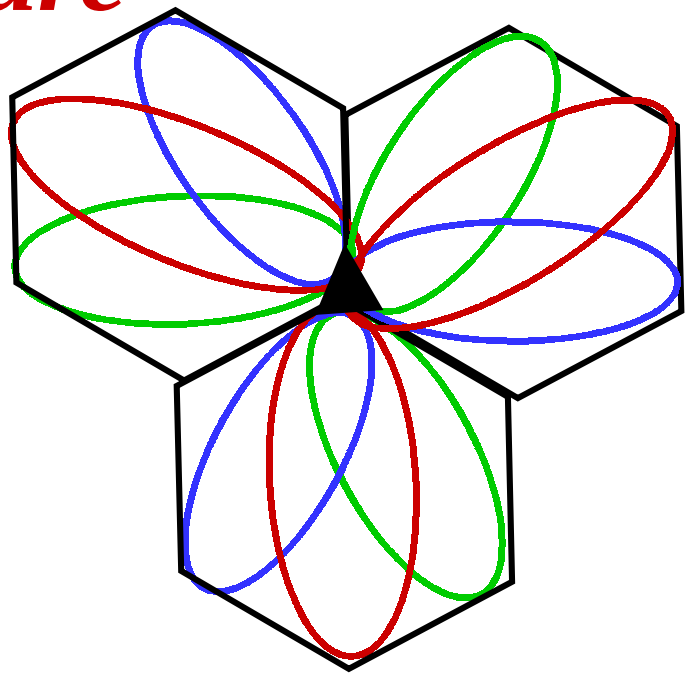


Uncorrected Spectrum

Converged Output Spectrum

Clean Input Signal

3G Multibeam Architecture



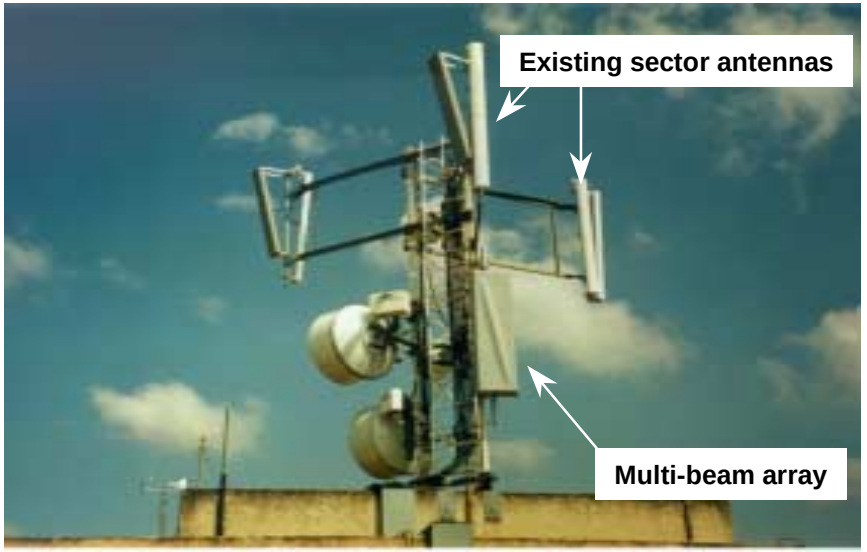
- **Practical Multibeam experience**
  - World's first 'uplink/downlink' smart antenna trial in commercial network in 1998
  - Smart multibeam base-station part of Nortel's new IS136 deployment for AWS
- **Multiple narrow downlink beams**
  - Maintain coverage footprint
  - Reduce other cell interference
- **Reverse link**
  - Dual polarised beams for good diversity gain
- **Increased capacity**
  - For mixed low rate, high rate multi-media users
  - 2-3 times capacity advantage

Multibeam antenna architecture enhances C/I for significant capacity gain

IS-136 MultiBeam Antenna Tech Trial

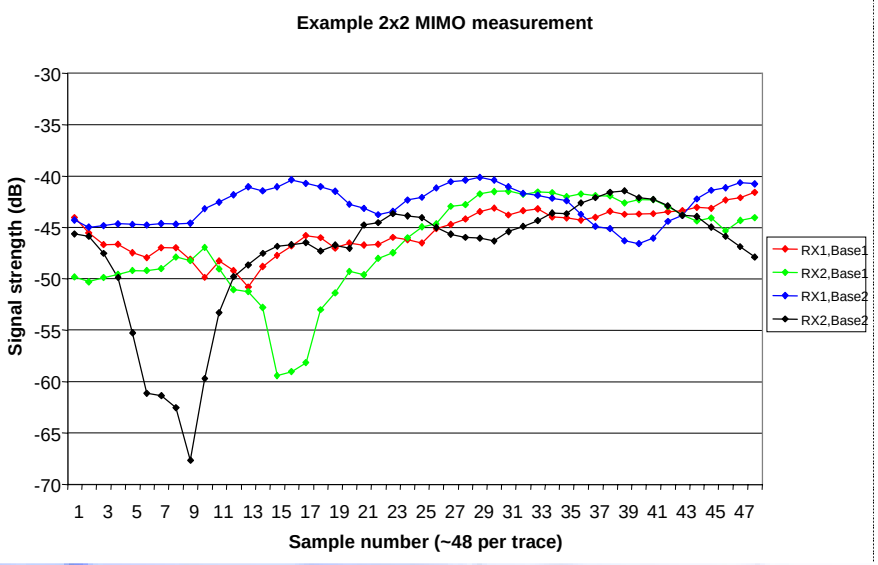
- World's first smart antenna trial of up & downlink beamforming supporting commercial traffic in an IS-136 TDMA network
- Successfully undertaken on Cellcom's network in heavily loaded, dense urban region in the centre of Haifa (May - August 1998)

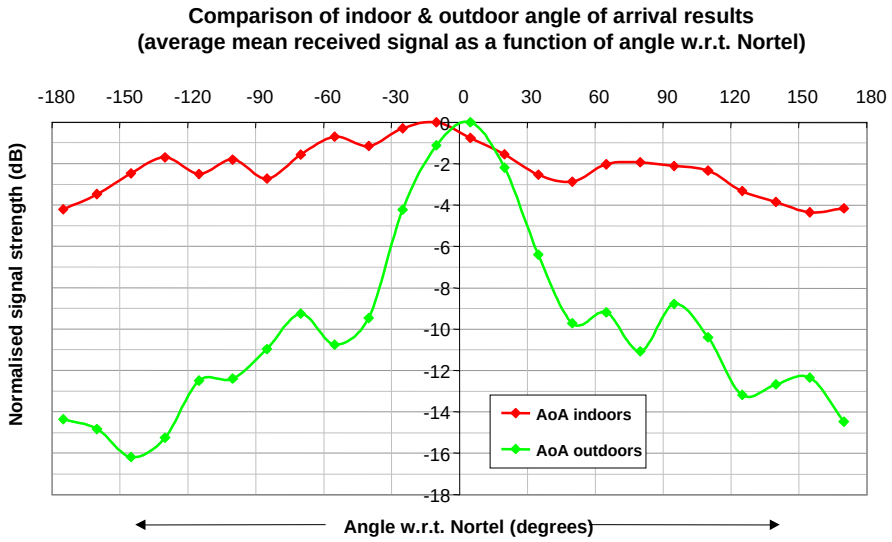
- **Integrated MultiBeam base station design using RF beam forming and multi-carrier PA technologies based on the current Nortel Urban product**
- **Proven in a typical dense urban deployment with antennas mounted close to average roof-tops**
- **Confirmed significant C/I benefit (3dB gain on forward and reverse link) and robust handover operation**



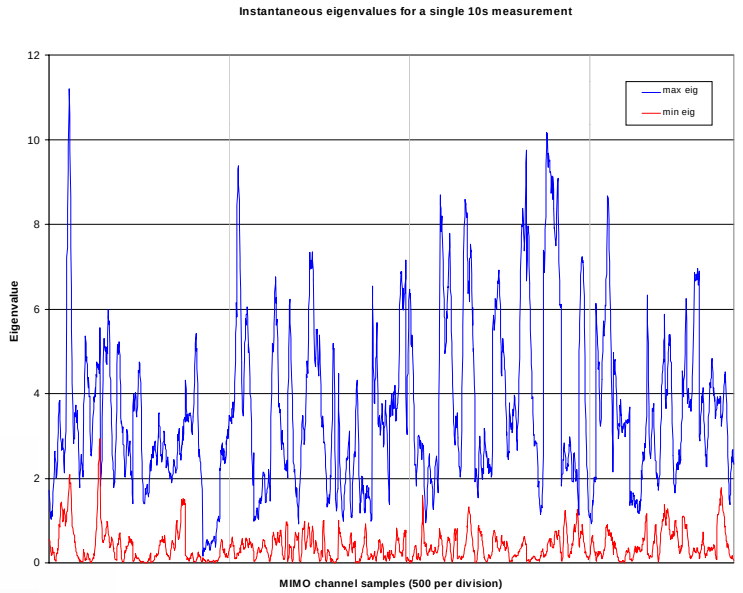
MultiBeam antenna installed at trial cellsite

MIMO Channel Characterisation

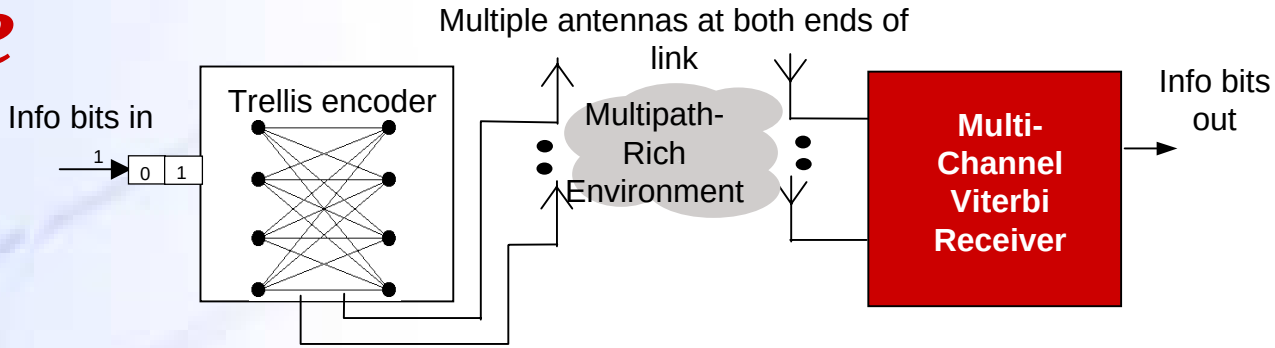




- Channel characterisation underpins Nortel's radio system design and performance evaluation
- Unique measurement facilities developed by Nortel's WTL to assess Space-Time Coding capacity gains for future wireless access



Space Time Coding



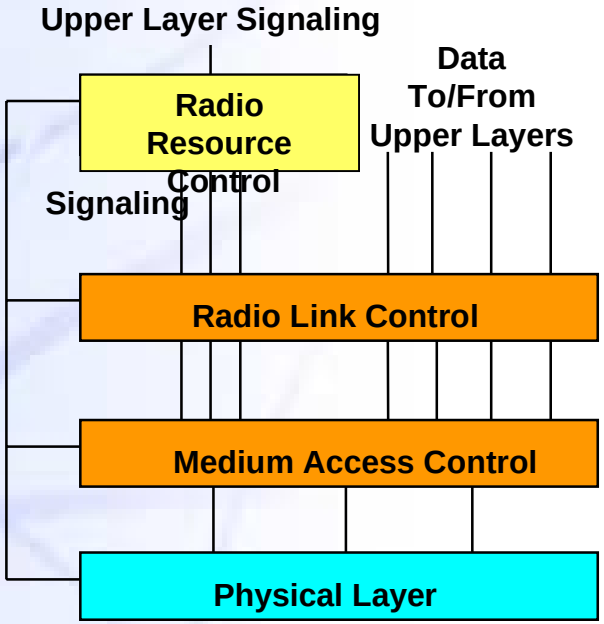
- **New concept, takes advantage of multipath effects**
  - multiple transmission paths in urban environment
  - each path affected by different fades
  - transmit from & receive by multiple antennas
  - ‘space’ & ‘time’ coding reduces probability of lost bits due to fading on individual paths
- **Substantial gains possible,**
  - small number of antenna elements, simple ST codes
  - capacity gains if interference limited or BW limited systems

STC can deliver up to 4x spectral efficiency, up to 10x capacity gain

RRM and Layer 2 Technology for 3G

Control

- Power Control
- Handover
- Admission Control
- Load Control
- Packet Scheduling



Error recovery, link layer adaptation for varying QoS

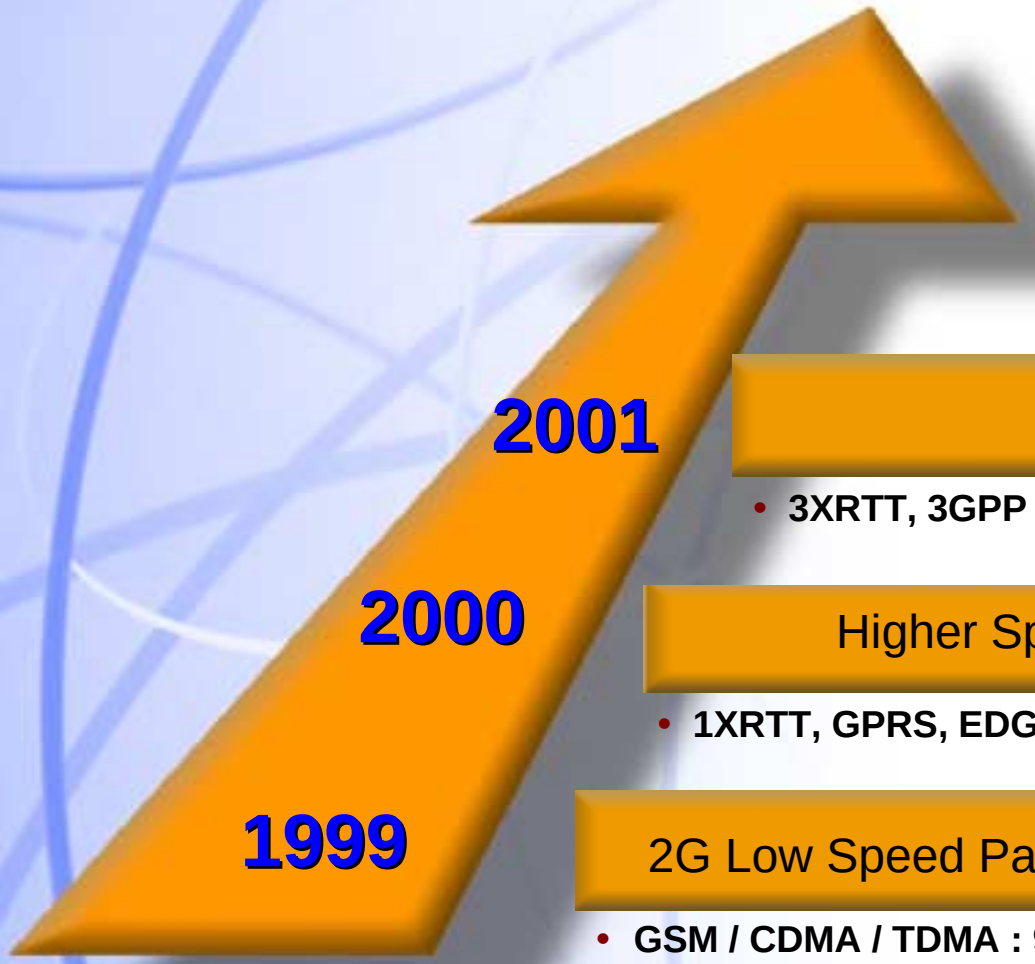
Scheduling & QoS prioritization for different physical channels

- Led industry in characterizing 1xRTT packet data performance. Evaluation methodology and extensive documented results being used by customers as industry benchmarks
- Provided insight to operators on how to optimize revenue as a function of different design tradeoffs e.g. per user vs per sector throughput
- In-depth front-end characterization provided engineering guidance for product design and basis for field trial comparative assessment. Served to identify potential risk areas for early resolution
- Leveraging our 1xRTT knowledge for UMTS product development and 4G advances

RRM and Layer 2 for 4G

- Technology program focused on providing industry-leading order of magnitude increase in aggregate cellsite capacity and in peak data rates.
- RRM and Layer 2 focused on providing efficient utilization of significantly higher radio capacity
  - Minimize overhead – x 10 reduction in cost/Mbit/s
  - Rapid channel access and release for bursty packet data – x 10 improvement over 3G
  - Support large user populations
  - Provide ‘always on’ environment
  - Dynamic QoS and bandwidth management
  - More complex control mechanisms to support enabling physical layer and adaptive antenna processing (e.g. OFDM, adaptive modulation, hybrid ARQ, STC, fast cell site switching, multibeam & tracking beam cell sites)
- Improving patent portfolio
  - 26 patent disclosures in 2000

Beyond 3G



4G Very High Speed Wireless Internet

- **Future Standard**
- **2 - 20 Mbps**
- **x 10 capacity over 3G; 1/10 cost / bit**
- **Seamless interconnection with 3G, W- LANs, fixed networks**

3G Multimedia

- **3XRTT, 3GPP : 144 kbps - 2 Mbps**

Higher Speed Packet Data

- **1XRTT, GPRS, EDGE : 9.6 - 384 kbps**

2G Low Speed Packet and Circuit Data

- **GSM / CDMA / TDMA : 9.6 - 19.2 kbps**

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4G Futures Program

- Establish a leadership position in the definition of the 4G standard
  - Have strong influence on future technology choices
    - Based on intensive simulation & prototyping
  - Provide a system context for new technology decisions
  - Build IPR inventory, for positive 4G license
  - Be first to market with product
- Program consists of system concept development, simulations & prototyping
- Engage other technology trend leaders pre standardization
- 3G benefits
  - Deliver appropriate mid-life improvements to 3G systems
  - Ensure best evolution strategy from 3G
  - Agree amortization / new opportunity window with operators

4G System Objectives

Parameter (Nomadic) - 5 MHz	*Link*	*UMTS*	*Target*
Aggregate Data Thro'put per Cell, Mbps	Forward	3.8	100
	Reverse	3.8	30
User Peak Data Rate, Mbps	Forward	0.4	20
	Reverse	0.4	5
Spectral Efficiency, bps/Hz/cell/carrier	Forward	0.8	20
	Reverse	0.8	6
Dormant to Active Transition Time, secs		2.0	0.1

First System Choices

Downlink

- **Downlink treated as one or more "fat pipes" shared among many users**
- **COFDM, dual mode STC / STTD per user depending on channel conditions, 1024 carriers**
- **MAC scheduling to support fast data rate adaptation**
- **Fast channel driven feedback for adaptive modulation & coding**
- **Multi beam per sector, or tracking beam**
- **Interference avoidance co-ordinated among radio access points**
- **Enhanced ARQ**
- **Dual diversity terminal reception**

Uplink

- **Synchronous CDMA for reduced intra-cell interference**
- **Fast signaling channel for average C/I and preferred RAPs for next frame**
- **Multi user detection at base station**
- **ARQ with soft combining**
- **Fast access MAC for small packets**
- **Tracking beam**

Not all choices will be adopted by the standard, but positions Nortel for fastest re-alignment to final standard

Summary

- **Fusion of Wireless and the Internet is well underway**
- **The wireless industry is developing higher rate, higher efficiency 3G product deployments in the 2000-2002 timeframe**
- **Advanced technology can meet network demands**
  - improved cost effectiveness for existing services
  - new services for increased revenue opportunities
  - optimum leverage of pre-3G investment
- **The industry needs to anticipate the next phase of evolution - meeting subscriber expectations for very high speed affordable Internet access at rates comparable to the fixed networks and W-LANs**