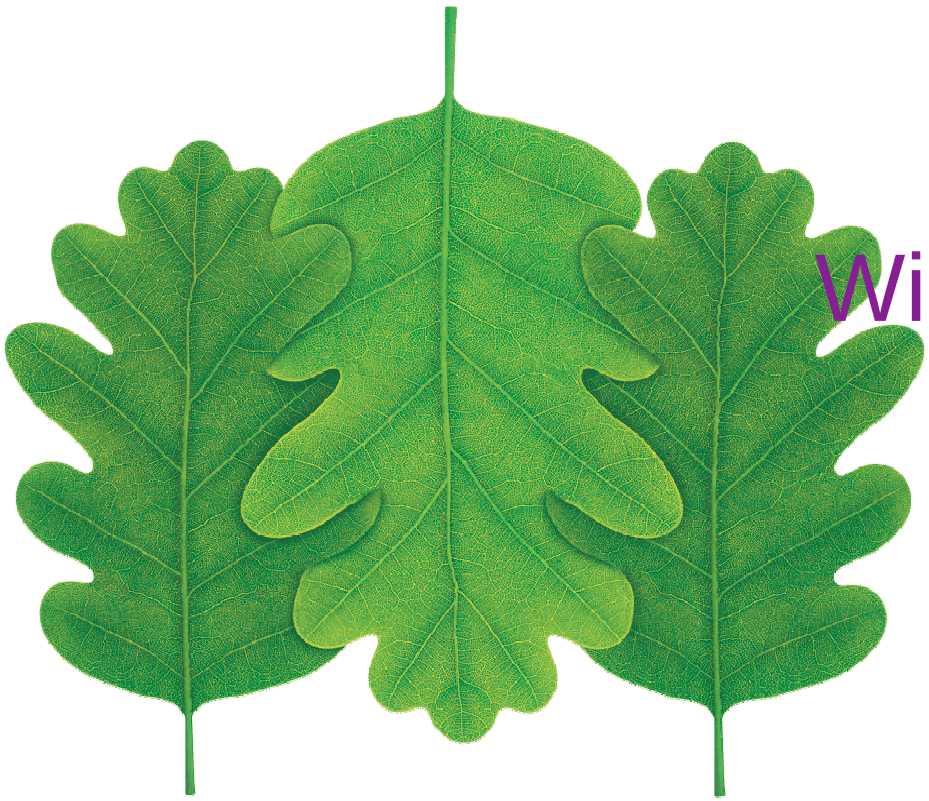

Forward View of Wireless Technologies

April 2006

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Agenda

- Technology Trends
- Regulatory Trends
- Business Trends
- Brief Technology Overview
  - WWAN Point to Point and Point to Multipoint
  - Wireless Wide Area Mobile Broadband
  - Wireless Local Area Networks (WLAN)
  - Wireless Identification Technology
  - Wireless Sensor Technology
  - Inter Technology Seamless Roaming

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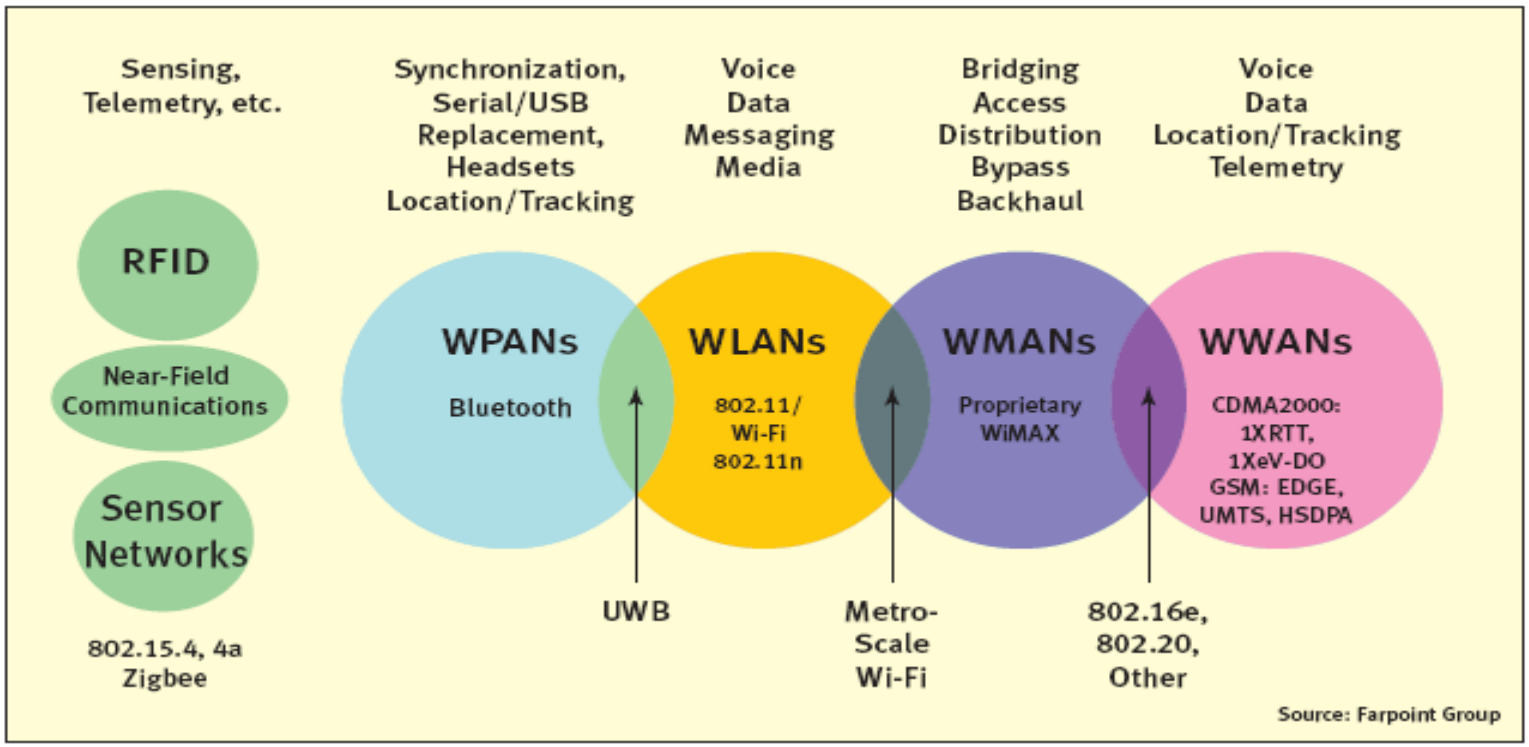
Technology Landscape



Source: Farpoint Group

Wireless Technology Trends -General

- Integration of radio's onto silicon with memory and dedicated processor
  - Lower power and smaller devices
  - Digital Signal processing,
  - Faster processing allowing OFDMA, CDMA and a host of modulation and signal processing techniques
- Wireless access chips being integrated into computing platforms, consumer electronics, sensor/control networks
  - Centrino, embedded WiFi, Wireless Personal Area Networks, Zigbee, RFID
- Software Defined Radio, Software Radio, Cognitive Radio technologies are emerging
  - taking advantage of advances in radio integration into silicon and new agile front end techniques
  - Driven by public safety and Military organizations

Semiconductor Companies – Wireless is a growth market

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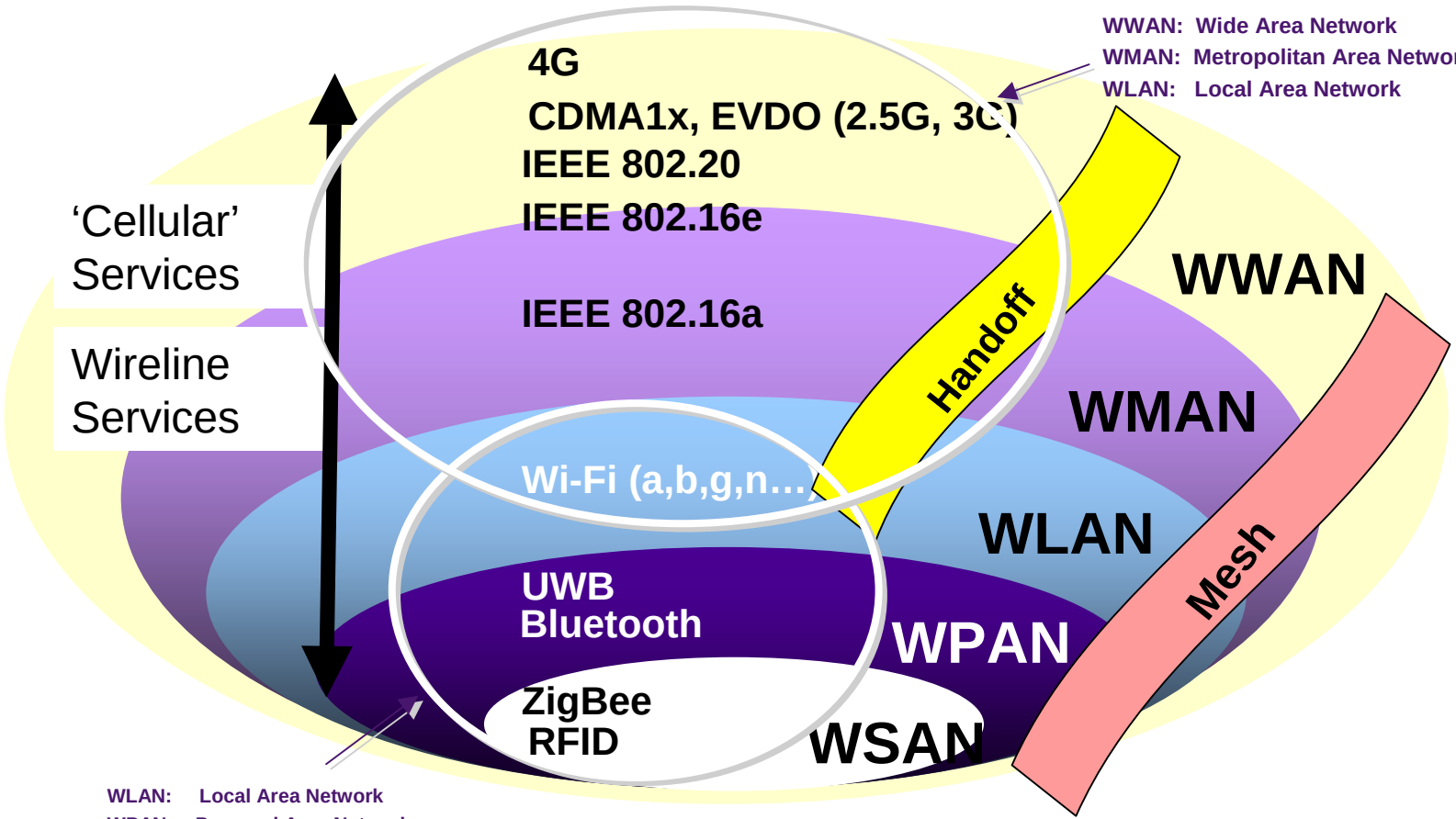
Wireless Trends Inter- Technology Roaming



- Multiple Technologies
- Spectrum C-oexistance
- Complementary Solutions

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Wireless Technology Trends - WWAN

- New standards – increasing BW and modulation order for higher data throughput
  - WiMAX – up to 20 MHz channel width, 64 QAM modulation
  - EVDO Rev C/802.20 –up to 20MHz channel width – 64 QAM
  - Wifi – 20MHz BW, 802.11n – 40 MHz BW
  - UWB -802.11b
- Move to OFDM to keep symbol rate low per tone and aggregate tones – better multipath performance for NLOS conditions
  - WiMAX, DVB, 802.11a,g , 802.20, EVDO Rev C, 3GPP LTE
- Standards moving to MIMO and adaptive beam forming antenna techniques to for link budget gain
  - Multiple Input Multiple Output – diversity gain in fading environment
  - Adaptive beam forming – focus energy on user and provide better spatial isolation

Taking advantage of processing power, chip integration and DSP techniques to increase link budget and spectral efficiency

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EVDO (Rel A)

Table 2 – Different configuration for link adaptation in 1x-EVDO

Modulation	QPSK	QPSK	QPSK	QPSK	QPSK	QPSK	QPSK	8-PSK	QPSK	16-QAM	8-PSK	16-QAM
Code Rate	1/5	1/5	1/5	1/5	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3
Packet size in ms	26.67	13.33	6.67	3.33	6.67	1.67	3.33	3.33	1.67	3.33	1.67	1.67
Bits per packet	1024	1024	1024	1024	2048	1024	2048	3072	2048	4096	3072	4096
Number of slots	16	8	4	2	4	1	2	2	1	2	1	1
NDR in kbps	38.4	76.8	153.6	307.2	307.2	614.4	614.4	921.6	1228.8	1228.8	1843.2	2457.6

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Trends- WLAN, WPAN, Sensors

- MESH AD HOC configurations
  - Self configuring, self healing
  - Easy set up
  - MESH WiFi, Zigbee
- Multiple Technologies on a Device
  - Cell phone, PDA, - multiple chip sets – taking advantage of integration

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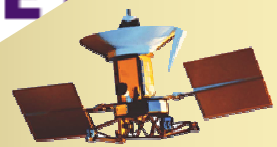
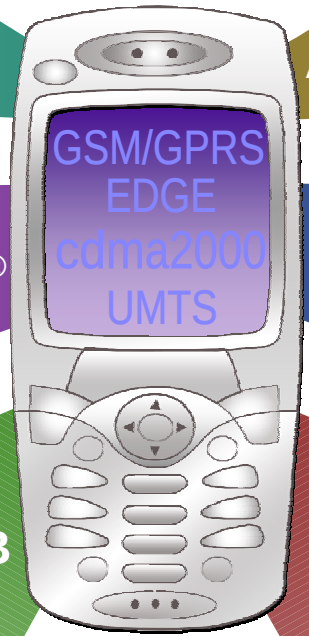
Multiple Technology Devices

Multiple radios
Multiple applications
Concurrency



- VoWLAN
- Internet access
- E-mail

Wi-Fi



A-GPS

- E911 services
- Location-based services
  - Marketing
  - Travel & entertainment
    Mapping & navigation

Bluetooth®

- Talk/Listen wire free
- Info synchronization
- Printing

Digital TV

- View live broadcast TV
- Download movies

UWB

- Send video/images to PVR or TV for viewing

FM Radio, RFID
…and Future
Wireless Technologies

Reality Check – WWAN

- New technologies have smaller range and require a tighter grid of site deployment
  - 64 QAM – higher C/I requirements - low probability of achieving 64 QAM
  - Higher order modulation only useful in a small range deployment
  - Tighter grid means more hand-off in mobility situations limiting the system throughput
- MIMO and Adaptive Antennas add complexity and cost to devices and base stations
  - value in real world deployments needs to be quantified
  - Improves link budget, but not enough

Macro Coverage technologies are not delivering higher throughput and capacity for the same coverage as NLOS voice networks

Need Link Budget improvements – 25-40 dB ?

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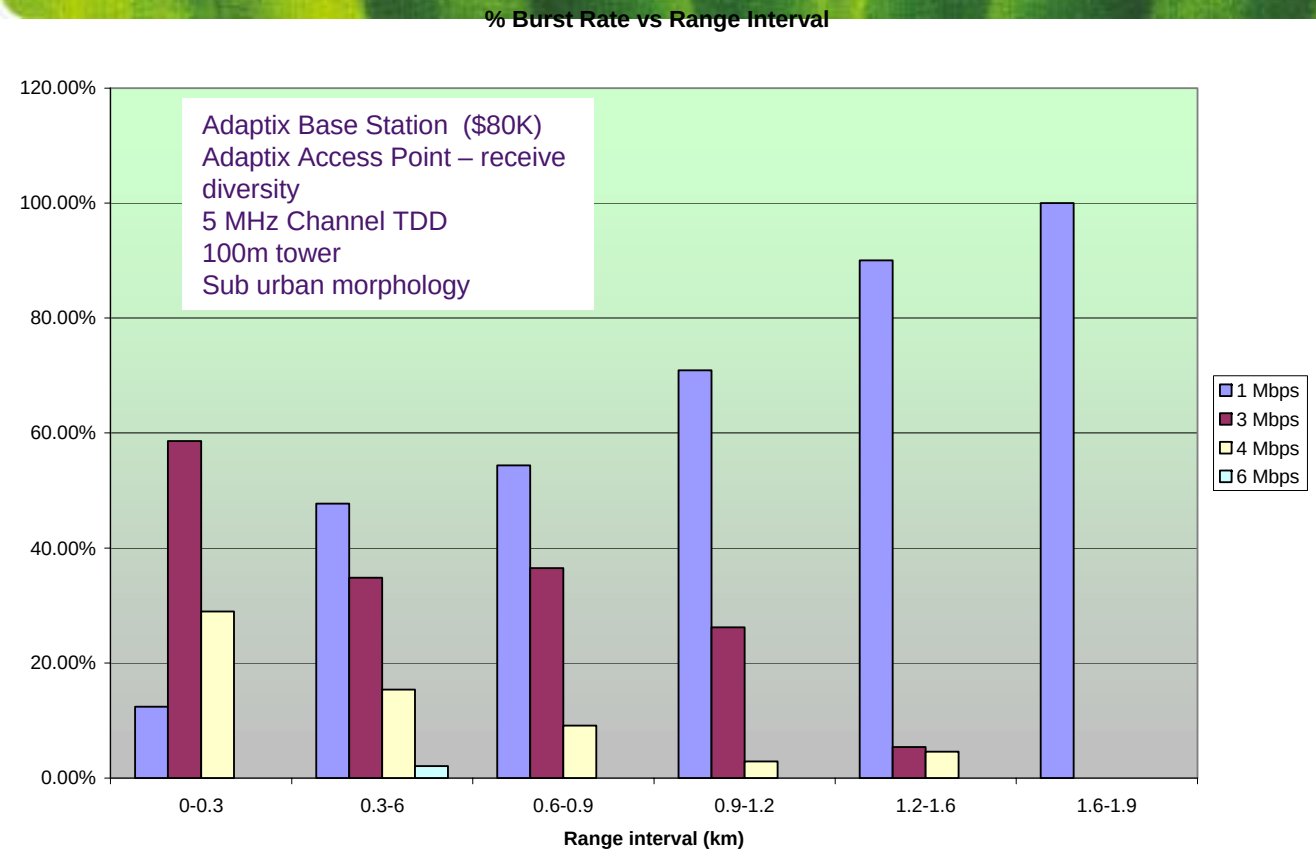
WiBro Trial – 2.3 GHz – Mobile Broadband - NLOS



Could not establish connection passed 1.9 km

Reality Check WWAN

- Wide Area WiMAX and 3G technologies – the air interface is a shared pipe
  - Sustainable throughput per user decreases with more users
  - No user has dedicated bandwidth
  - Service Level Agreements – not economical

- Adaptive Coding and Modulation and C/I based on the shared pipe act as policy server overriding any other QOS mechanisms
  - IP protocols and QOS mechanisms assume that only the load is changing, not the transport medium

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Reality Check – WLAN, WPAN, Sensors

- MESH AD-HOC networks are great for connectivity but performance is “AD HOC”
  - Latency built up and bandwidth reduction tradeoff with the number of hops in a MESH
- 802.11 WiFi MESH – complicated by CSMA which causes rapid reduction in bandwidth
- Multiple Radio integration on devices – battery power problem and interference problem

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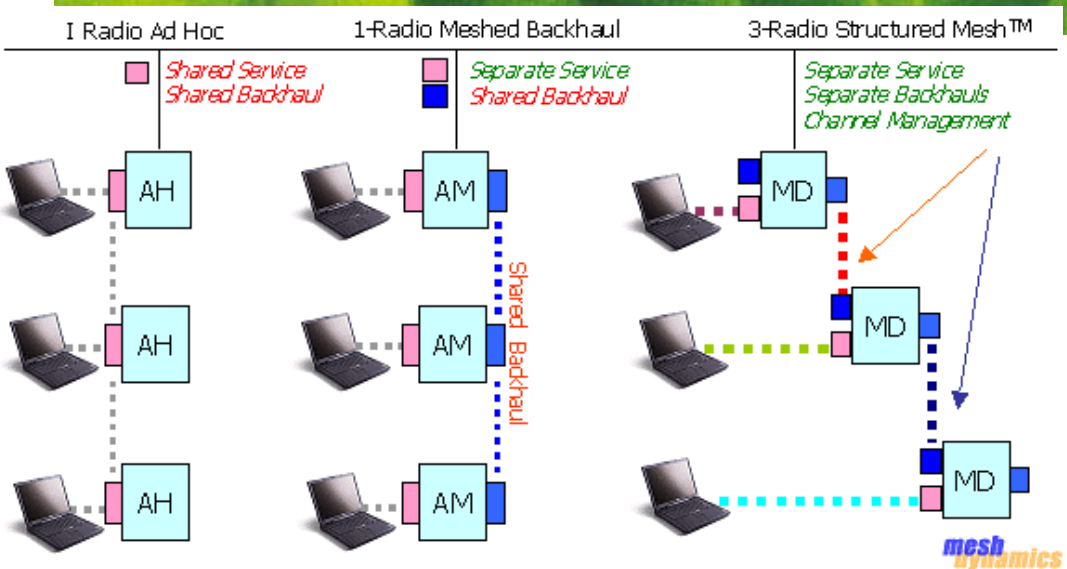
Mesh Architecture Options



Nortel and Cisco Products

- Performance of MESH improves, the more radio's involved
- 1 Radio < $500 per AP – but everyone is interference to each other
- 2 Radio – around $2000 per AP
- Most expensive – 3 Radio > $3000 per AP– send and receive at the same time on the mesh connection

Cost Performance Trade-off – more radios per AP better performance For significantly more cost

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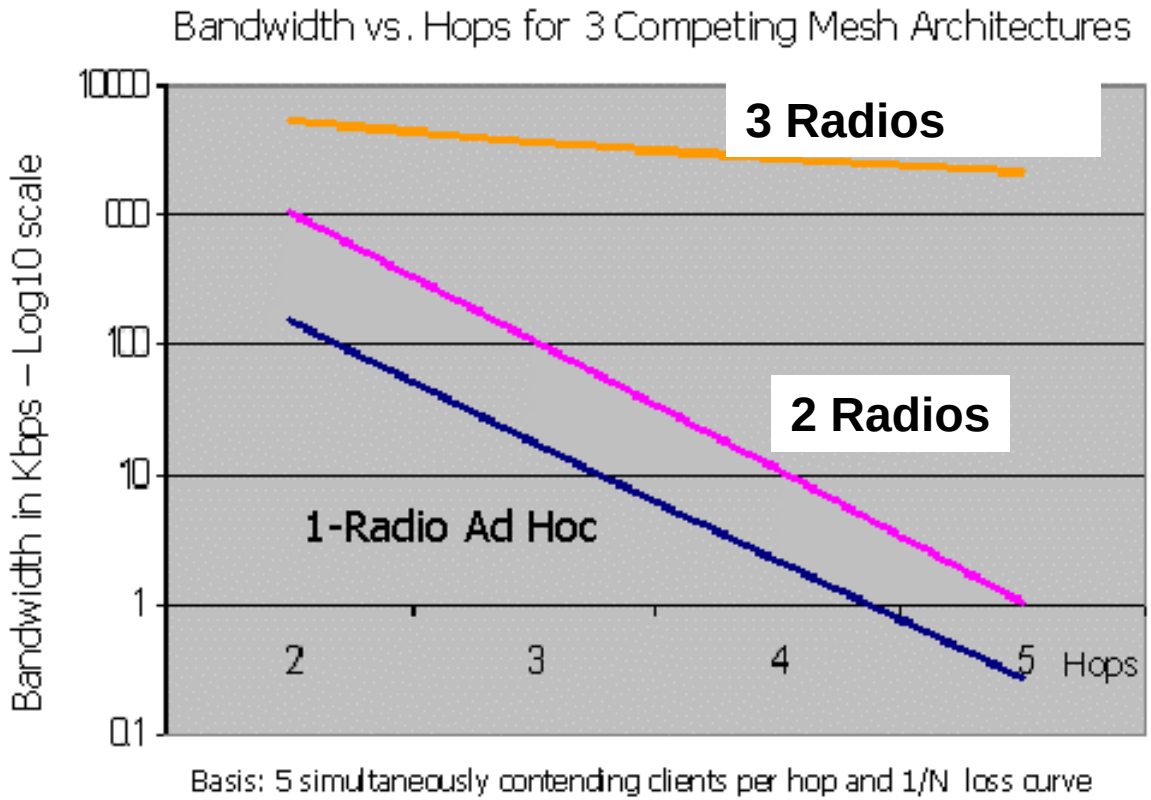
MESH Performance Comparison



- The more hops, the more radio contention the less bandwidth/user and the build up of latency
- There is debate in industry that the above graphs are optimistic
  - Bandwidth decreases as 1/N^2 in some white papers

Reality Check – Inter-Technology Roaming

- 802.21 addressing inter-technology roaming but addressing only above layer 2 (layer 2.5 and layer 3)
- Problem:
  - Hand-off is a layer 1, layer 2 mechanism
  - Some technologies do not even have hand-off
  - Proprietary solutions trying to solve with a layer 3 – multiple connection solutions but reliability is unknown
  - Need standards on how to measure a signal and trigger setting up and taking down of connections

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Regulatory Trends

- Regulatory bodies starting to consider licensing “technology agnostic spectrum”
  - FCC, OFCOM, CEPT
- Reallocation of Broadcast TV spectrum – UHF, VHF, 700 MHz
  - Cable and Satellite TV penetration showing that broadcast spectrum is not being used
- Licensing spectrum above 2 GHz
  - 2.5 GHz, 3.5 GHz, 4.9 GHz
- More unlicensed spectrum becoming available
  - 5.4-5.9GHz, 3.6 GHz, Cognitive Radio 802.22

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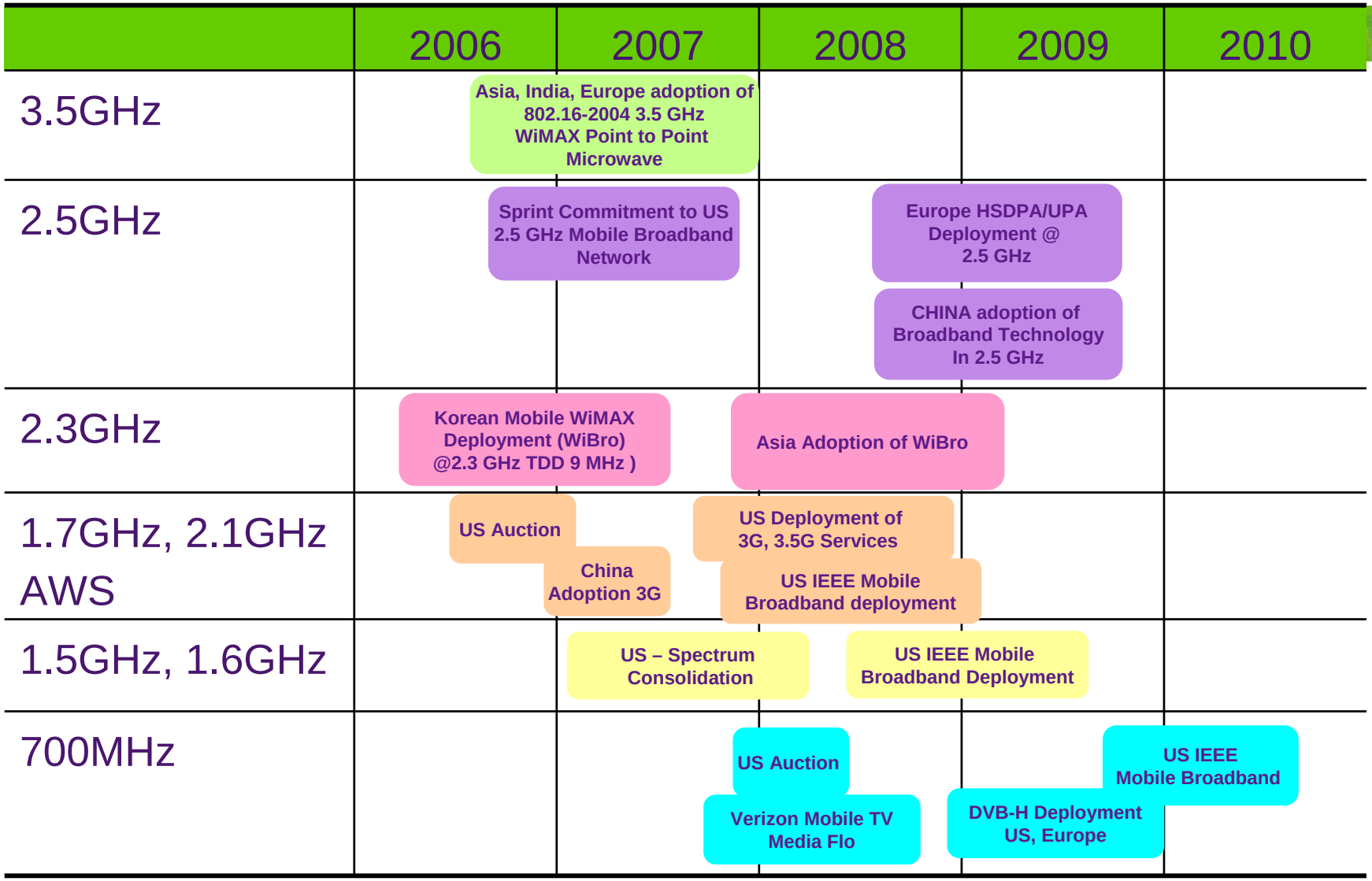
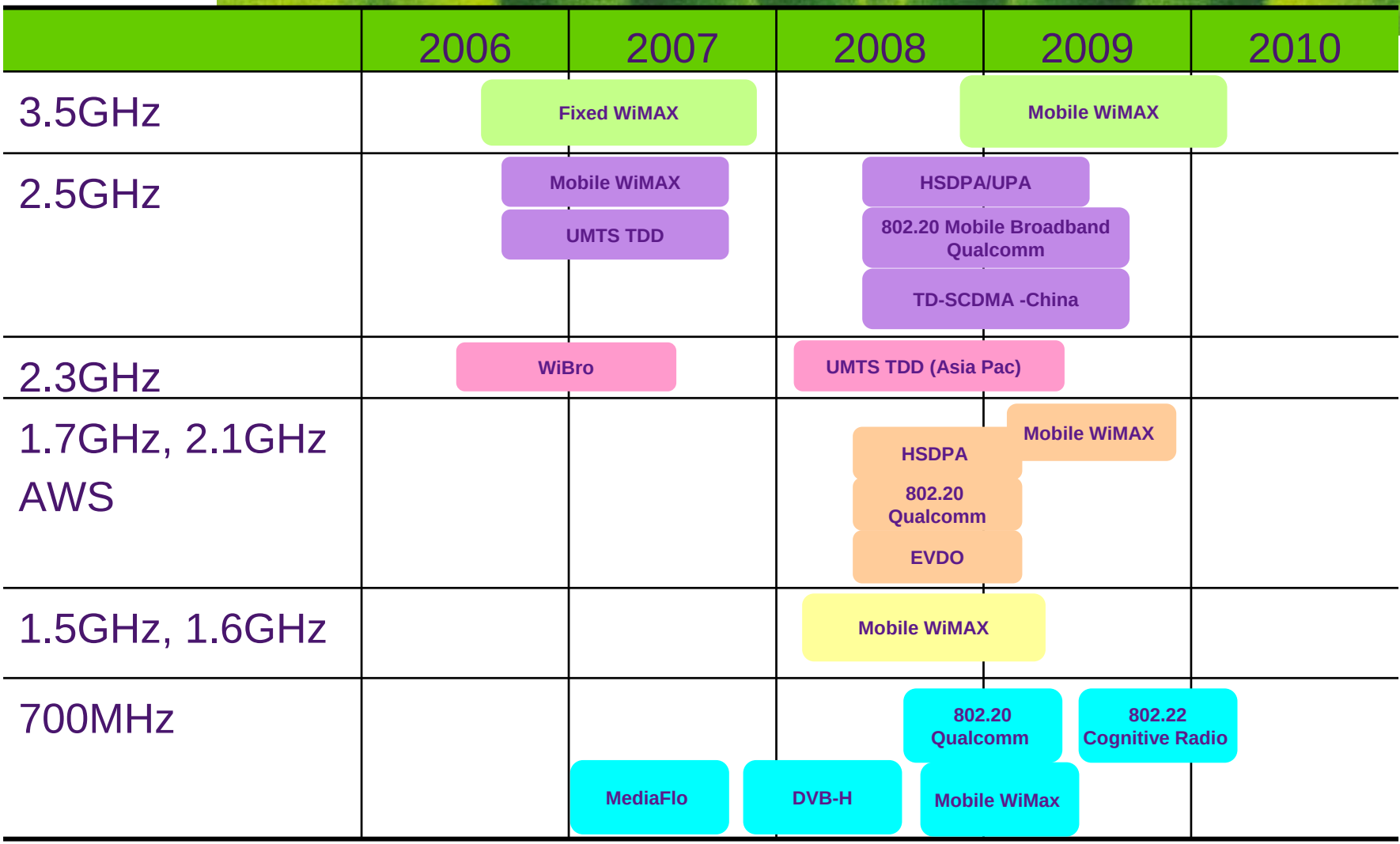
Spectrum Landscape



Source: TELUS Technology Strategy

Technology Competition



Source: TELUS Technology Strategy

Reality Check - Spectrum

- Higher spectrum does not propagate as well as current PCS 1.9 GHz or 800 MHz
  - Hurts mobile WiMAX business case
  - Need 35-40 dB more link budget without power increases (new physics required)
  - Creating a log jam of lobbying for lower frequencies (700 MHz)
- Technology Agnostic spectrum means technology

Chip makers pushing but spectrum and radio propagation pushing back

Importance of an Ecosystem

Triggers	Effects	End User Benefits
▪ **Numerous hardware manufacturers build embedded devices**	▪ **Variety of device form factors becomes available**	▪ **Choice of devices to address usage scenarios (PDA, laptop, handsets, etc.)**
▪ **Industry & regulatory bodies support the communications standard**	▪ **Drives volume of devices and network hardware due to standardization**	▪ **Affordable device, CPE prices make business case for adoption compelling**
▪ **'Heavyweight' Carriers or other big customers commit and deploy technologies**	▪ **Drives volume of devices and network hardware due to demand and momentum**	▪ **Business case for network infrastructure for carrier or other deployment creates an affordable service**

CDMA - EVDO	**GSM – 3GPP**	**WiMax Mobile**
TELUS, Bell, Verizon & Sprint	Rogers, Cingular, T-Mobile	
22 M Subs 24 Operators 14 Countries 142 Devices 20 Vendors	45 M Subs 81 Carriers 35 Countries 126 Devices 22 Vendors	0 M Subs 1 Carrier* 1 Countries 0 Devices ? Vendors

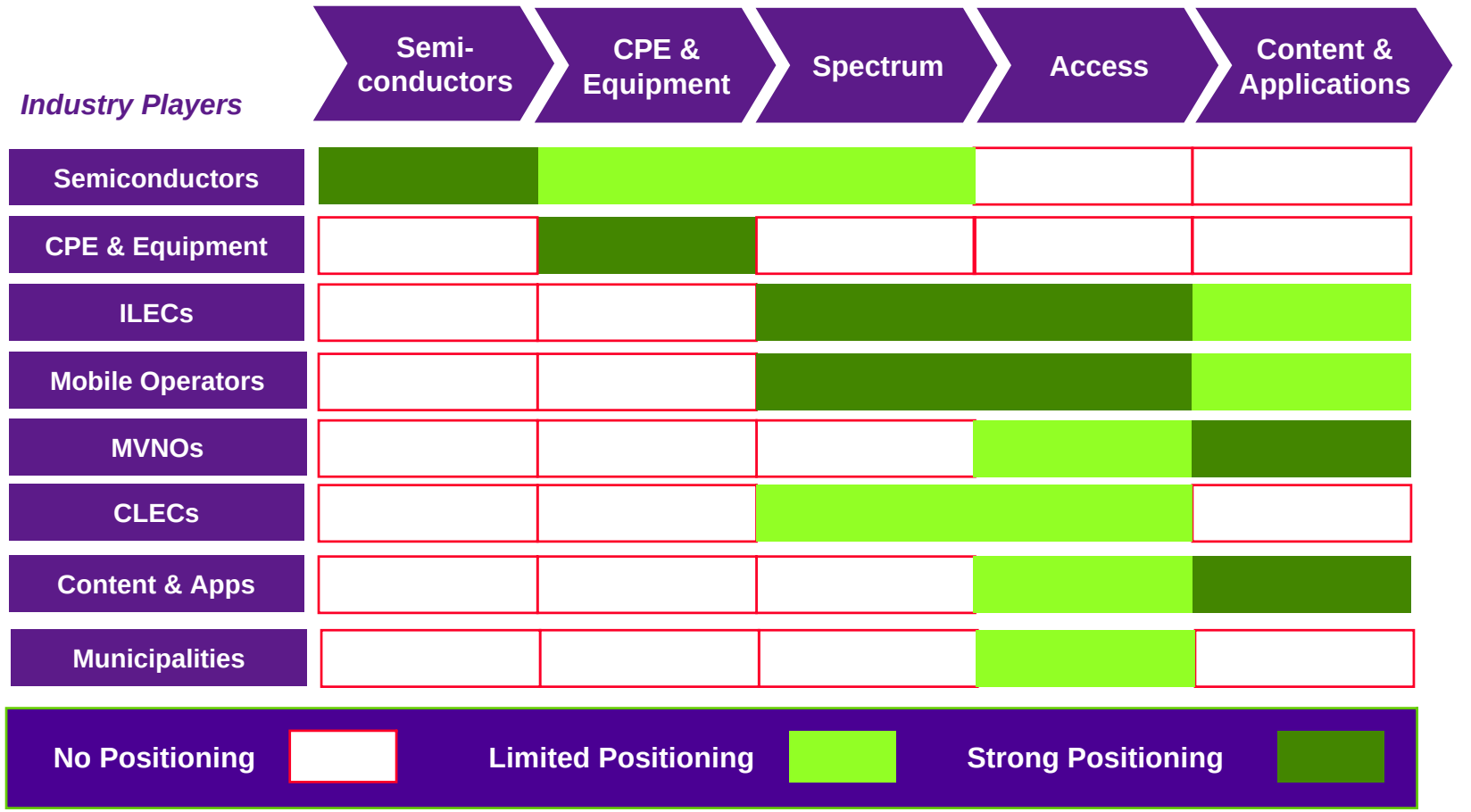
For a technology to proliferate and be affordable, the various stakeholders groups that influence the adoption of standards determine which standards will be adopted

Business Trends

- New players coming into value chain for wireless access
  - Content providers
  - MVNOs
  - Municipalities
  - ILECs
  - Internet service providers
- Mobilization of Internet Access
  - PDAs, Laptops – portable access demanded
- Mobilization of Entertainment
  - Gaming, TV, VOD

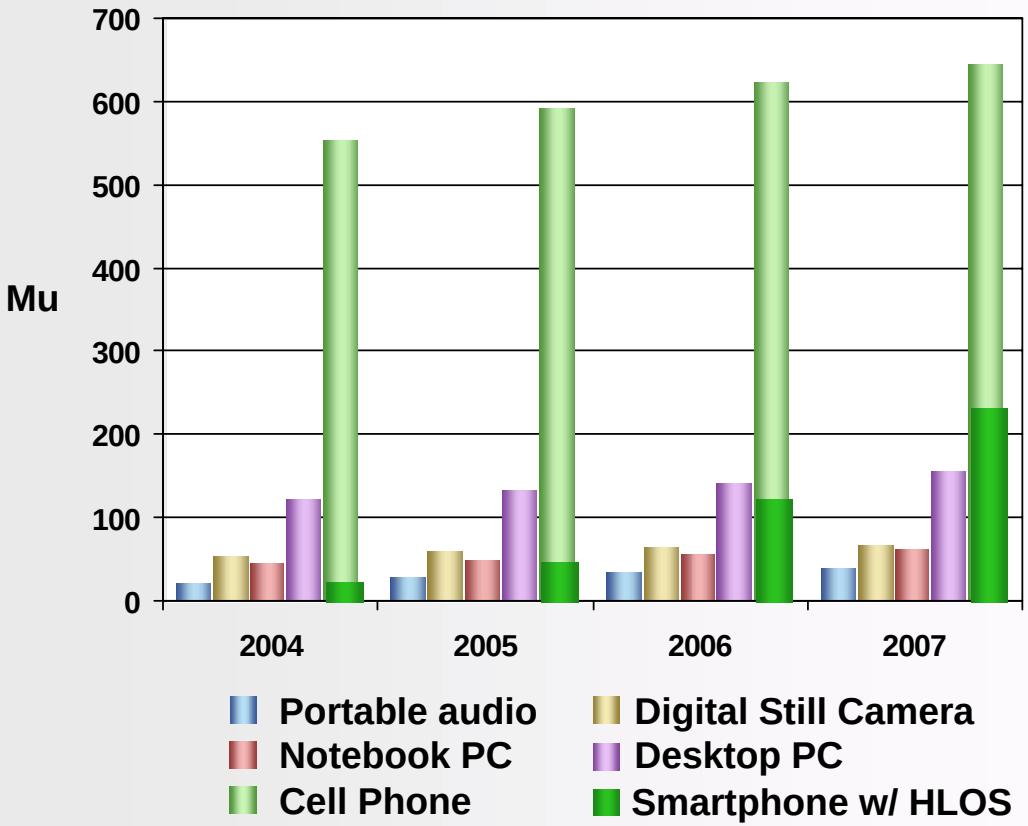
Broadband Wireless Access Value Chain

Broadband Wireless Access Industry Value Structure



Wireless Handset is Most Important Platform for Integration of Consumer Electronics (CE) and Other Features

Shipments



Source: InStat, iSuppli

More than any other device, people will use cell phones to:

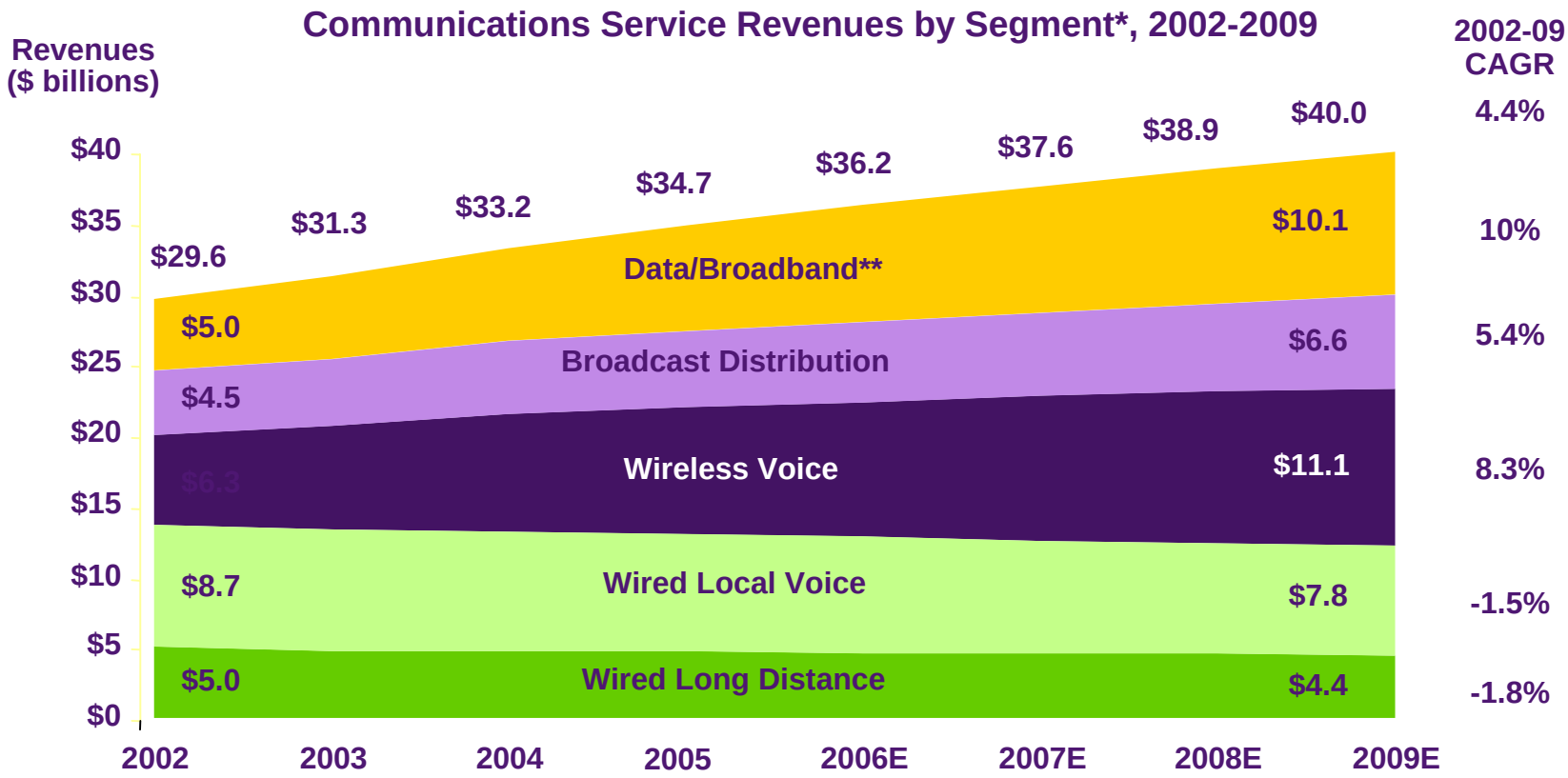
- Make phone calls!
- Access the Internet
- Organize their lives
- Listen to music (MP3)
- Take & send pictures
- Record & watch video
- Play games
- Use location based services
- Listen to FM Radio
- Watch broadcast TV

Reality Check – Business Trends

- Voice is still king – where revenue and margin come from
  - No clear path for data revenues
  - Data services ? - like the public intranet – lots one can do, but will it make money – what are the business relationships
  - Currently – data services are lost leaders to reduce churn on voice networks
- Voice revenue eroding – pushes consolidation to reduce costs

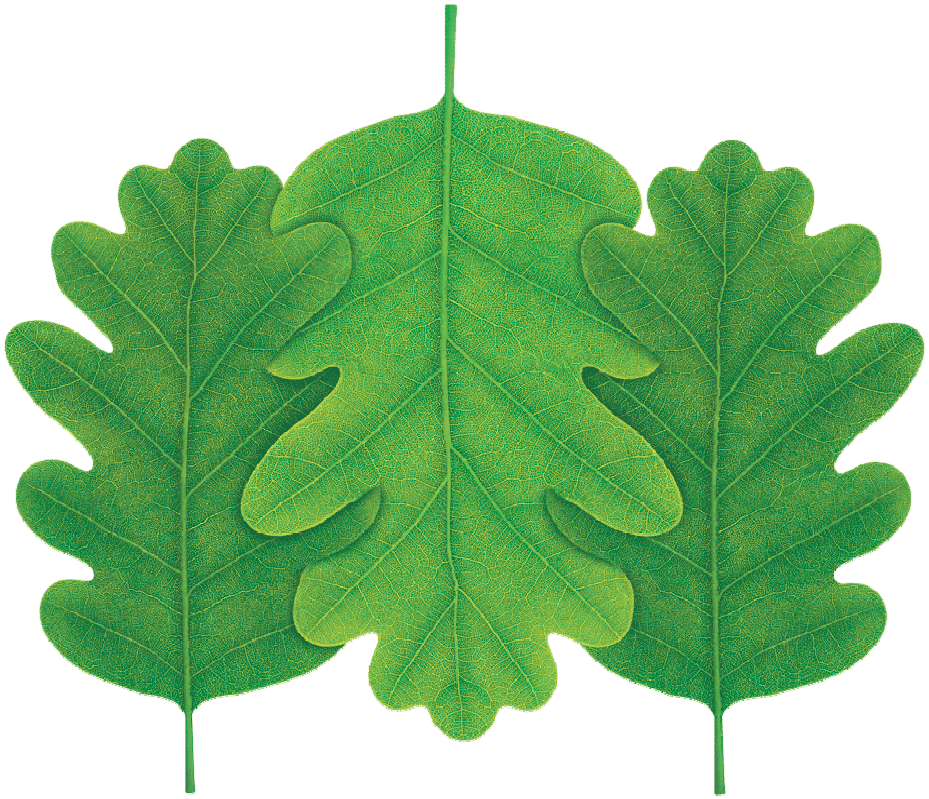
Communications Sector Revenue Breakdown

The Canadian Telecom market is anticipated to reach $40 bn in revenue by 2009, with most of the growth coming from Data and Wireless services



**Graphic depicts only selected industry segments and does not constitute the entire telecommunications industry.*
***Includes retail DSL, cable modem, corporate data and wireless data. Numbers may not add up due to rounding.*
Source: Yankee Group, North America Consumer Fixed-Line & Media, Business Fixed-Line, and Wireless/Mobile Forecasts (June 2005).

Technology Overview



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WWAN P2P,P2MP Roadmap

20-100Mbps + Enterprise Microwave
Not recommended as wired transport is ubiquitous with higher reliability

Proprietary
>6 GHz

Mature with a market
Spec Development
Available but untested And limited market

Up to 20 Mbps Enterprise Microwave

TDM Backhaul (Cellular)

E10

Wireless DSL

WiMAX 802.16-2004 3.5 GHz

- ***Standards complete and interoperability certification completed for 3.5 GHz profiles***
- ***Potential Global Ecosystem with backhaul and Business DSL***
- ***Rural Wireless DSL***
- ***Fixed Business DSL***
- ***Up to 18 Mbps peak***
- *Telus supports only where we have spectrum*
  - *Gap in major centres*

2006 2007 2008 2009 2010+

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WWAN - Capabilities

	Point to Point Proprietary	802.16-2004 Fixed WiMAX
Spectrum	> 6 GHz	3.5 GHz TDD, FDD
Peak Throughput per packet burst	>100Mbps	18 Mbps
Target Use	Point to Point Backhaul Business WAN	Point to Point Backhaul Point to Multipoint Business DSL Consumer DSL –Rural with subsidy
SLA Support	Med - High	High (ATM, Frame Relay mechanisms)
Mobility	Not Applicable; Line of Site Only	Not Applicable; Line of Site or Near LOS
Link Reliability	99.999% achievable	99.999% achievable

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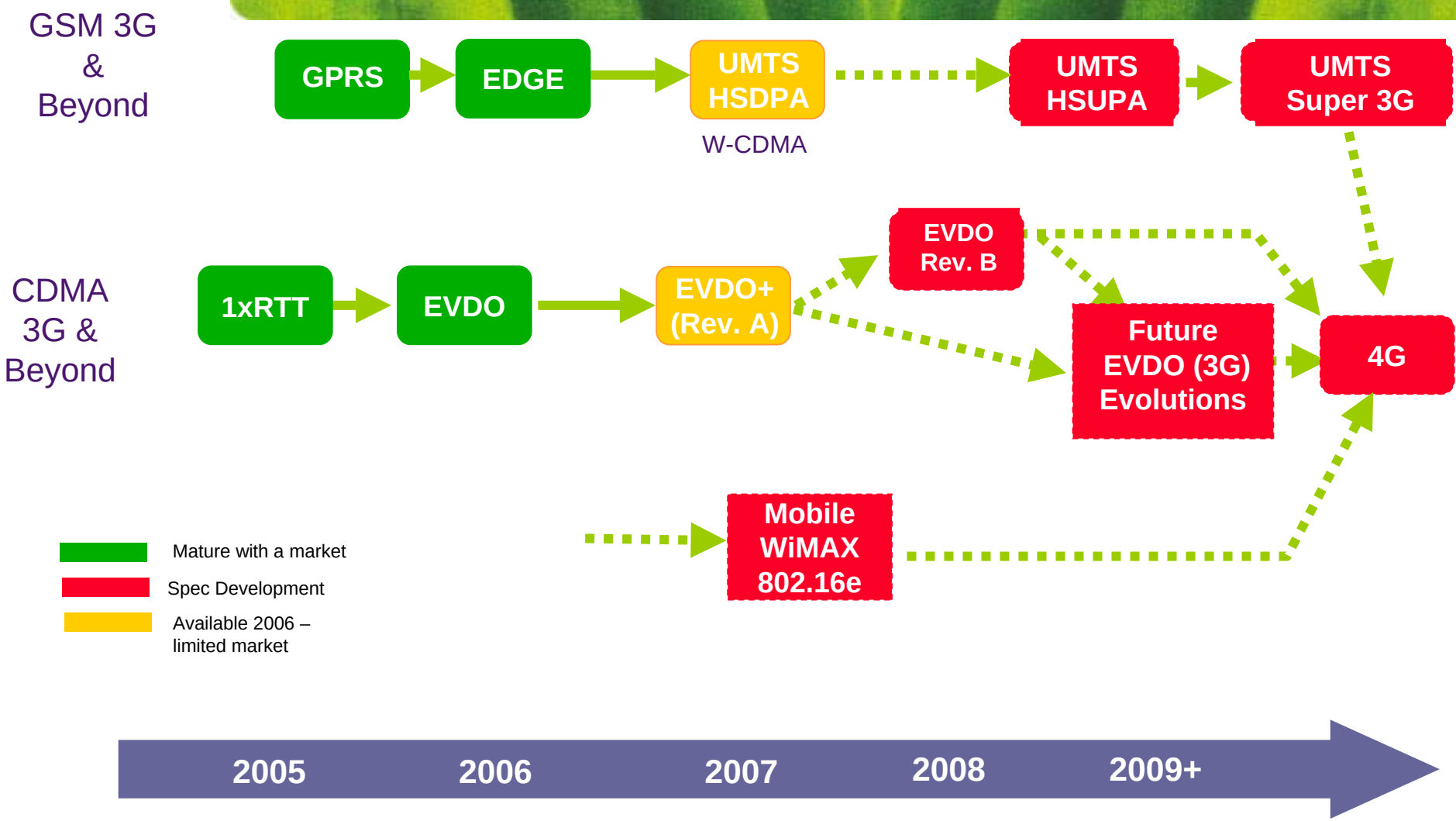
Wireless Wide Area Mobile Broadband



Wide Area Mobility -capabilities

	EVDO Rel 0	EVDO Rev A	EVDO Rev B*	EVDO Rev C**	Mobile WiMAX
Spectrum	1.9 GHz or 850 MHz	1.9 GHz	1.9 GHz	1.9 GHz	2.5 GHz
Throughput per packet burst per 1.25 MHz bandwidth	2.4 Mbps Down 153 Kbps Up Avg 400-600 kbps	3.1 Mbps Down 1.8 Mbps Up Avg 500-700 kbps			1Mbps
Target Use	Best Effort Services	Best effort + VOIP	BE +VOIP + Video >5fps	BE +VOIP + Video >5fps	BE +VOIP + Video >5fps
SLA Support	Not feasible	limited	limited	limited	limited
Mobility	150km/h hand-off	150km/h hand-off	150km/h hand-off	150km/h hand-off	Pedestrian (<60 km/h)
Link Reliability	99%	99%	99%	99%	99% on tighter grid

* Multi-carrier, 64QAM, 74 Mbps DL (on all 15 carriers), 27 Mbps UL

** OFDM, Smart Antenna, MIMO

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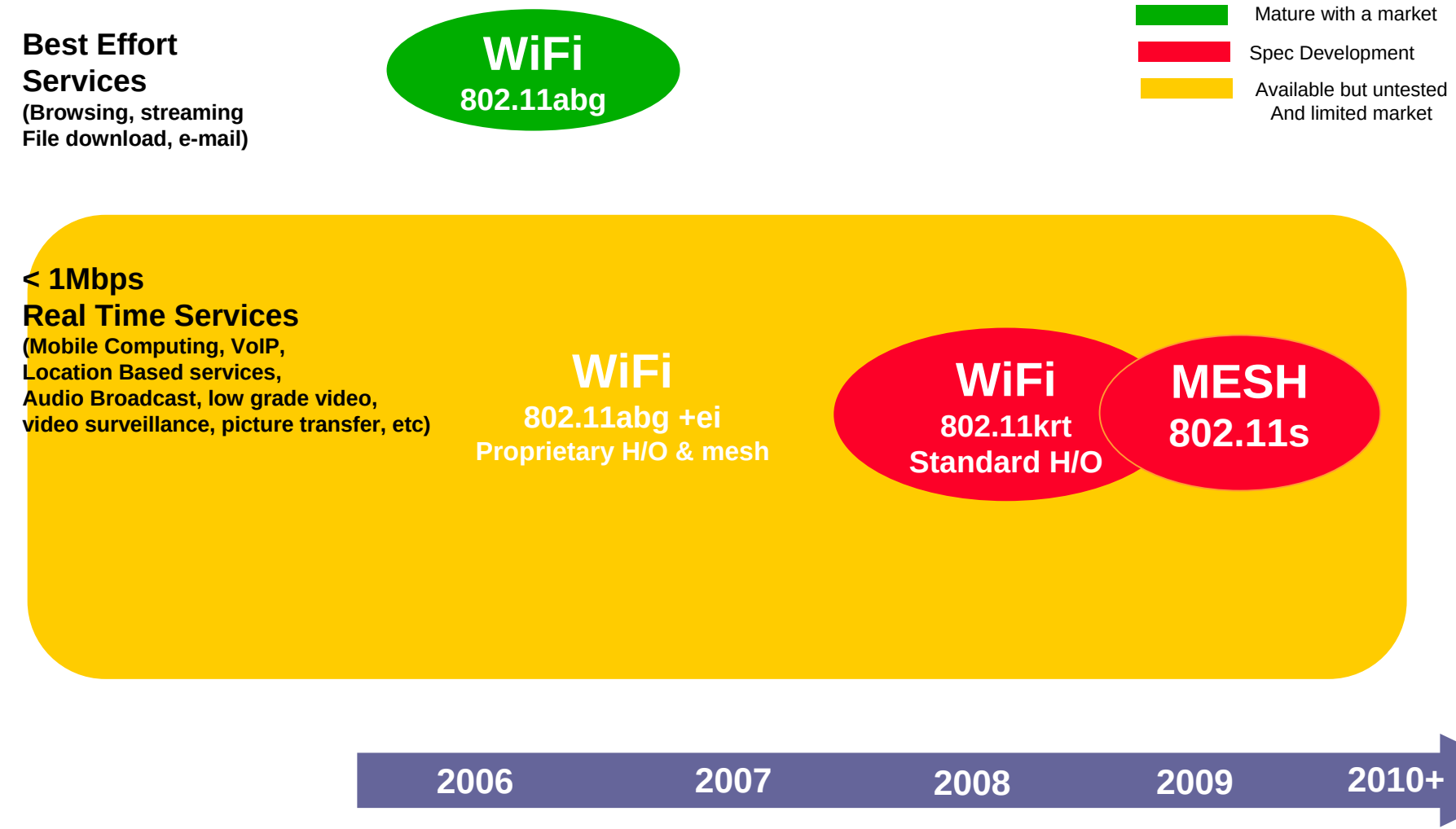
Wireless Local Area Networks



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WLAN Capabilities

	802.11 abg	802.11abg +ei with proprietary HO & MESH	802.11 krt	802.11s MESH
Spectrum	2.4&5.8 GHz unlicensed	2.4&5.8 GHz unlicensed	2.4&5.8 GHz unlicensed	2.4&5.8 GHz unlicensed
Avg Throughput per packet burst	1-2 Mbps	1-2 Mbps	1-2 Mbps	1-2 Mbps
Target Use	Cordless Ethernet in home or hotspots VOIP in home	Cordless Ethernet in home or enterprise Enterprise VOIP	Cordless Ethernet in home or enterprise Enteprise VOIP	Cordless Ethernet in home or enterprise
SLA Support	None	None	None	None
Mobility	None	Unreliable pedestrian	Unreliable pedestrian	Unreliable pedestrian
Link Reliability	<90%	<90%	<90%	<90%

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RFID

Asset Tracking
(Passive RFID Tags)

Class 0/1
RFID
EPC v1.1

-**Vertical specific**
- **Partnership possible**

Active RFID

Class 3-5
EPC v3

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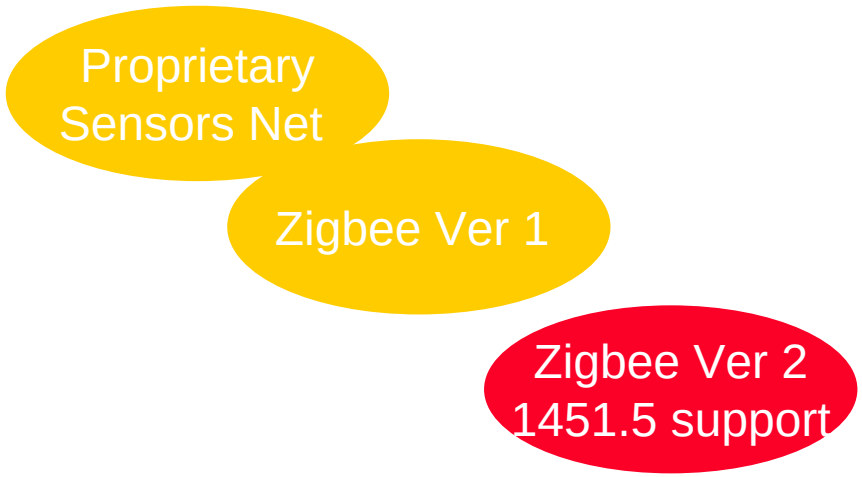
Wireless Sensor Technology

Home Automation Technology

Industrial Process Monitoring and Control



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RFID & Zigbee - capabilities

	RFID	Zigbee v 1	Zigbee v 2
Spectrum (unlicensed)	125,134 kHz 13.56 MHz 868-928 MHz 2.5 GHz	868 MHz 915 MHz 2.4 GHz	868 MHz 915 MHz 2.4 GHz
Avg Throughput per packet burst	< low bit rate	< 200 kbps	< 200 kbps
Target Use	Asset or product tracking	Control/sensor networks (home or enterprise)	Control/sensor networks (home or enterprise)
SLA Support	Not applicable	Not applicable	Not applicable
Mobility	None	None	None
Link Reliability	5-10% read errors	<90%	<90%

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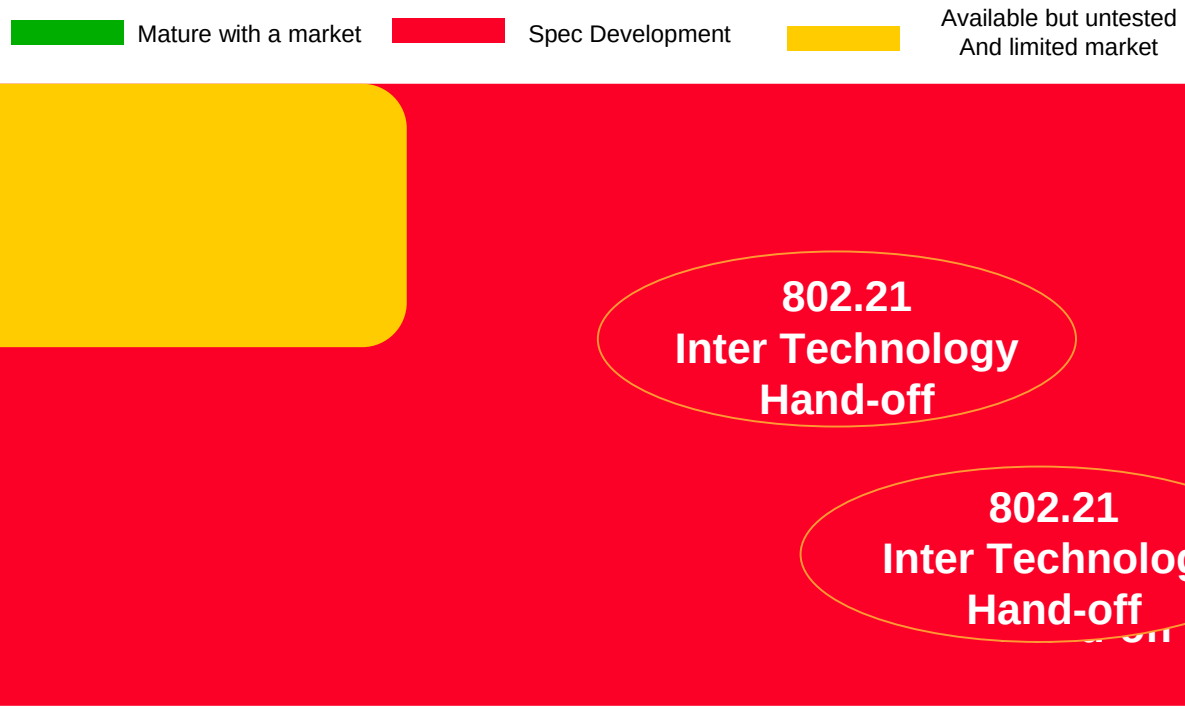
Inter-Technology Seamless Roaming



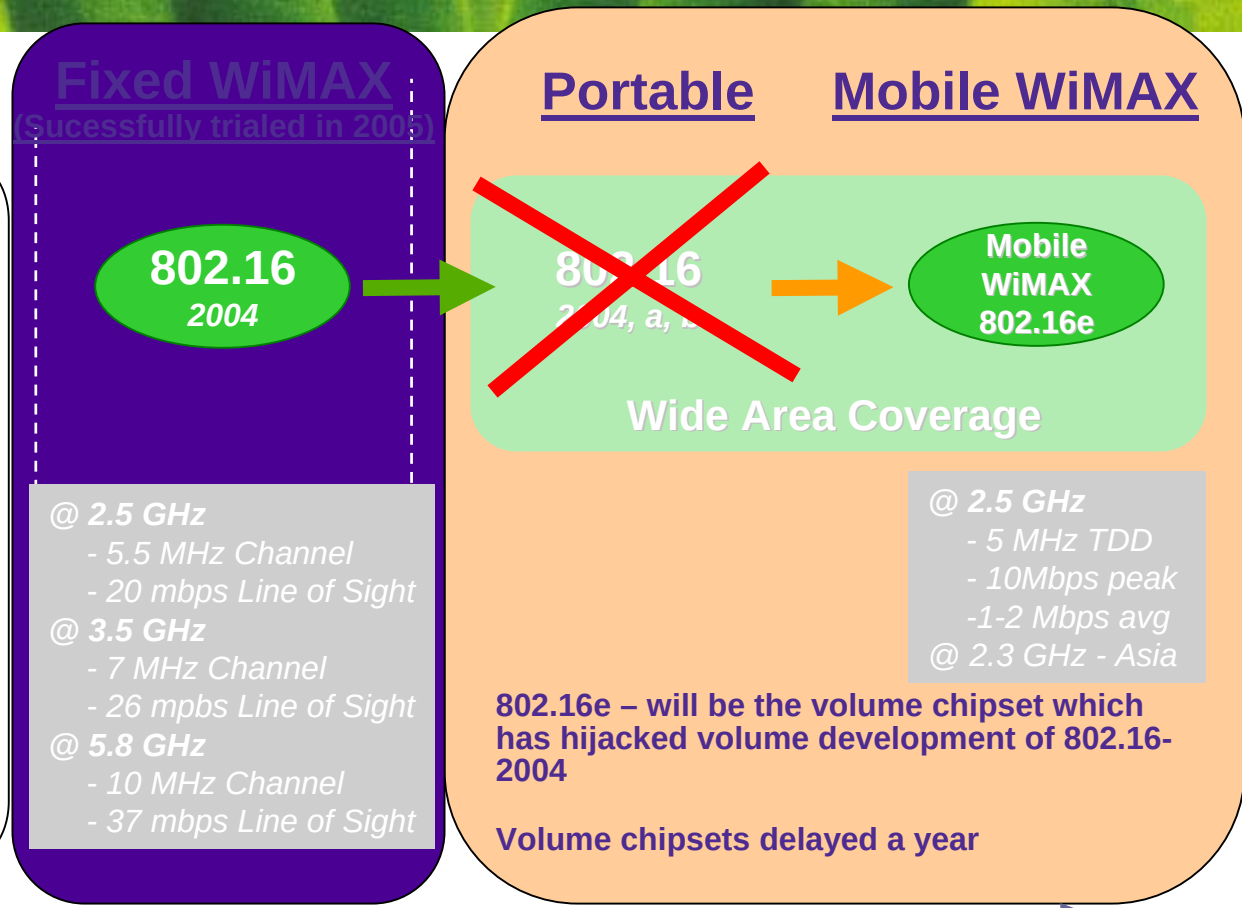
Capabilities

- link reliability < 90%
- Hand-off reliability <<90%
- SLA support - None

2006 2007 2008 2009 2010+

WiMax Definition

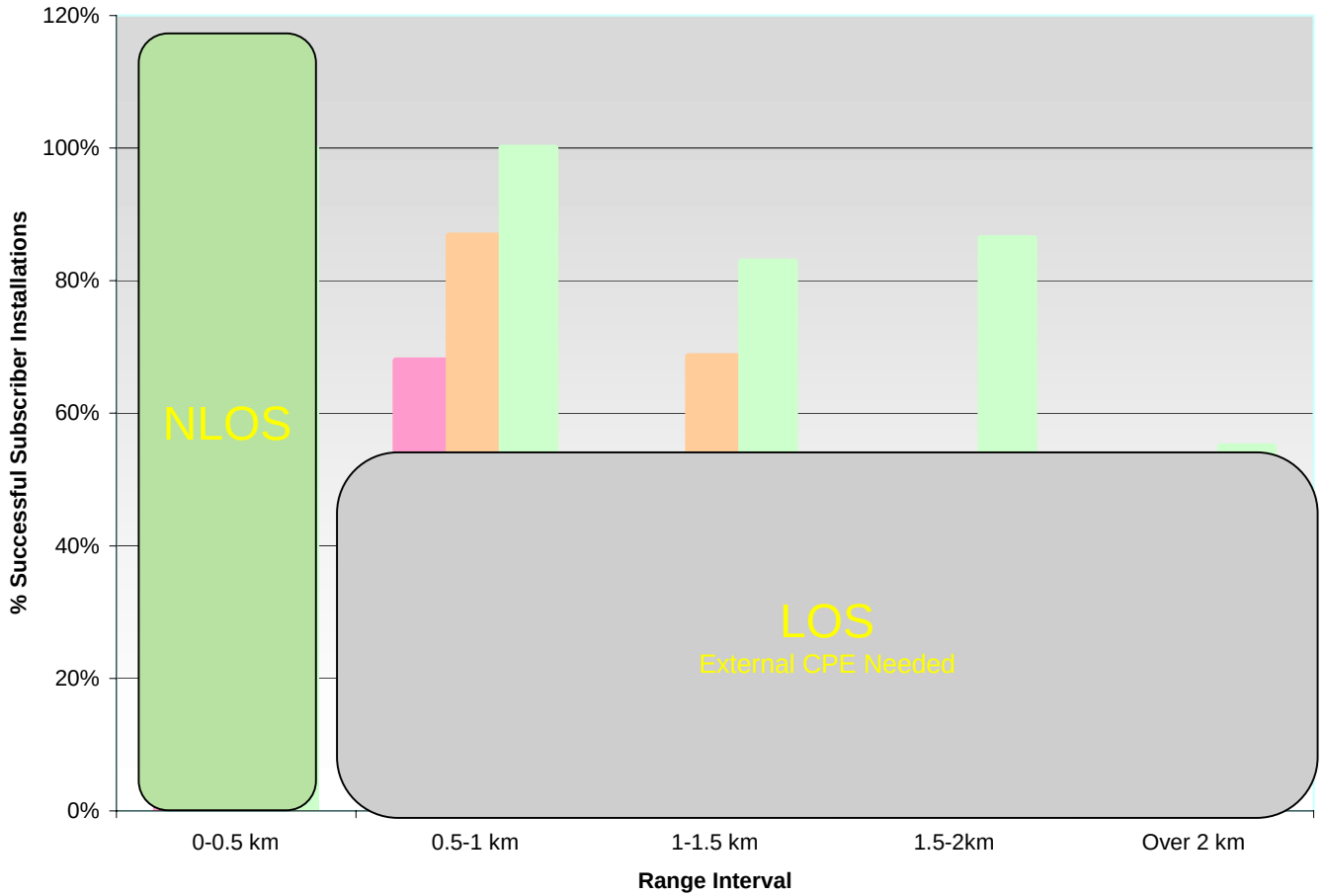
- **W**orldwide **I**nteroperability for **M**icrowave **Access**
  - 802.16 specification from 2001
  - For 10-66 GHz P to P backhaul
- **WiMAX** original goal was simple
  - Move backhaul technologies from proprietary to open standards
  - Reduce hardware costs
- **Intel** shifted the paradigm
  - Follow the success of WiFi with a successor networking technology
  - Target spectrum in 2-11 GHZ range
  - Contributed to driving standard toward a point-to-multipoint technology and eventual mobility
  - Integration of capabilities into chipsets



2001 | 2006 | 2007 | 2008

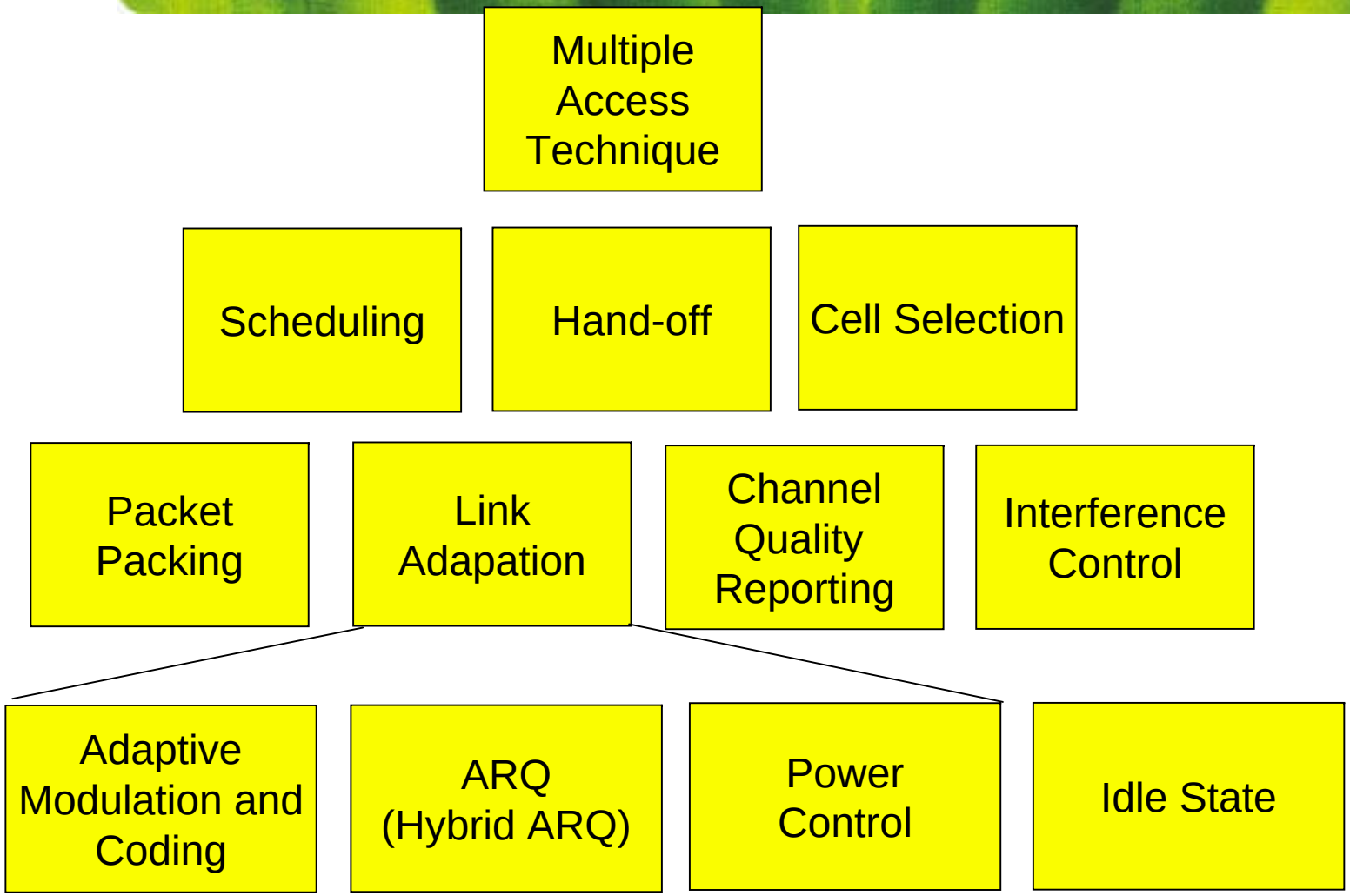
Range – Field Trial 3.5 GHz TDD

% Installations Achieving >3 Mbps Air Burst Rate vs Range Interval



- 2.5 GHz – 1 km range is LOS Range
- Higher site – move LOS range to 1.5-2km –very terrain dependent
- Mexico deployment of Nextnet – 1km Grid sites

Mobile Broadband RF Technology



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