

RAWCON 2003, Workshop WS1
WLAN and RFIC Technologies

*WLAN Market /
Technology Overview*

*Sanjay Moghe
Micro Linear Corp.*

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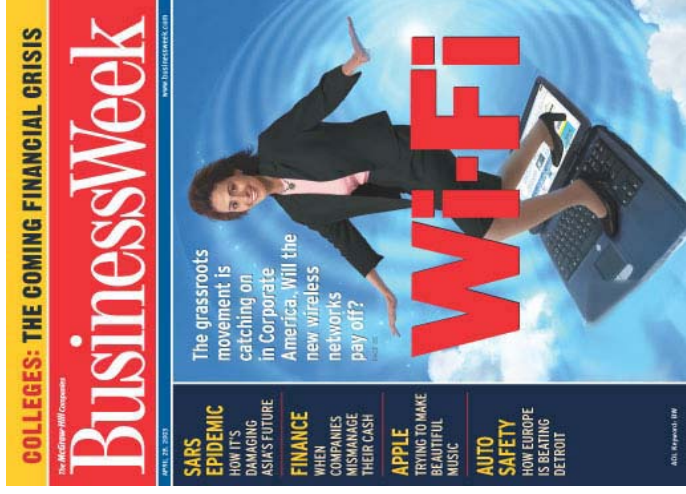
Outline

- **WLAN Market / Applications**
- WLAN standards
- WLAN technology
- Wireless convergence
- WLAN issues / Future trends
- Conclusions

In The News...

- Cisco buys Linksys for \$500m
- Intel spends \$300m to market Centrino chip
- Cometa Networks - joint venture of IBM, AT&T, Intel - 20,000 hotspots by 2005
- T-Mobile operates 2000 Starbucks hotspots
- Verizon installs Wi-Fi at pay phones
- Cisco announced Wi-Fi phones
- McDonalds - 1hr free with a Value Meal
- Publications are flooded with daily WLAN articles
 - More than 1 Million items on Google search on WLAN vs. 15K on RFIC

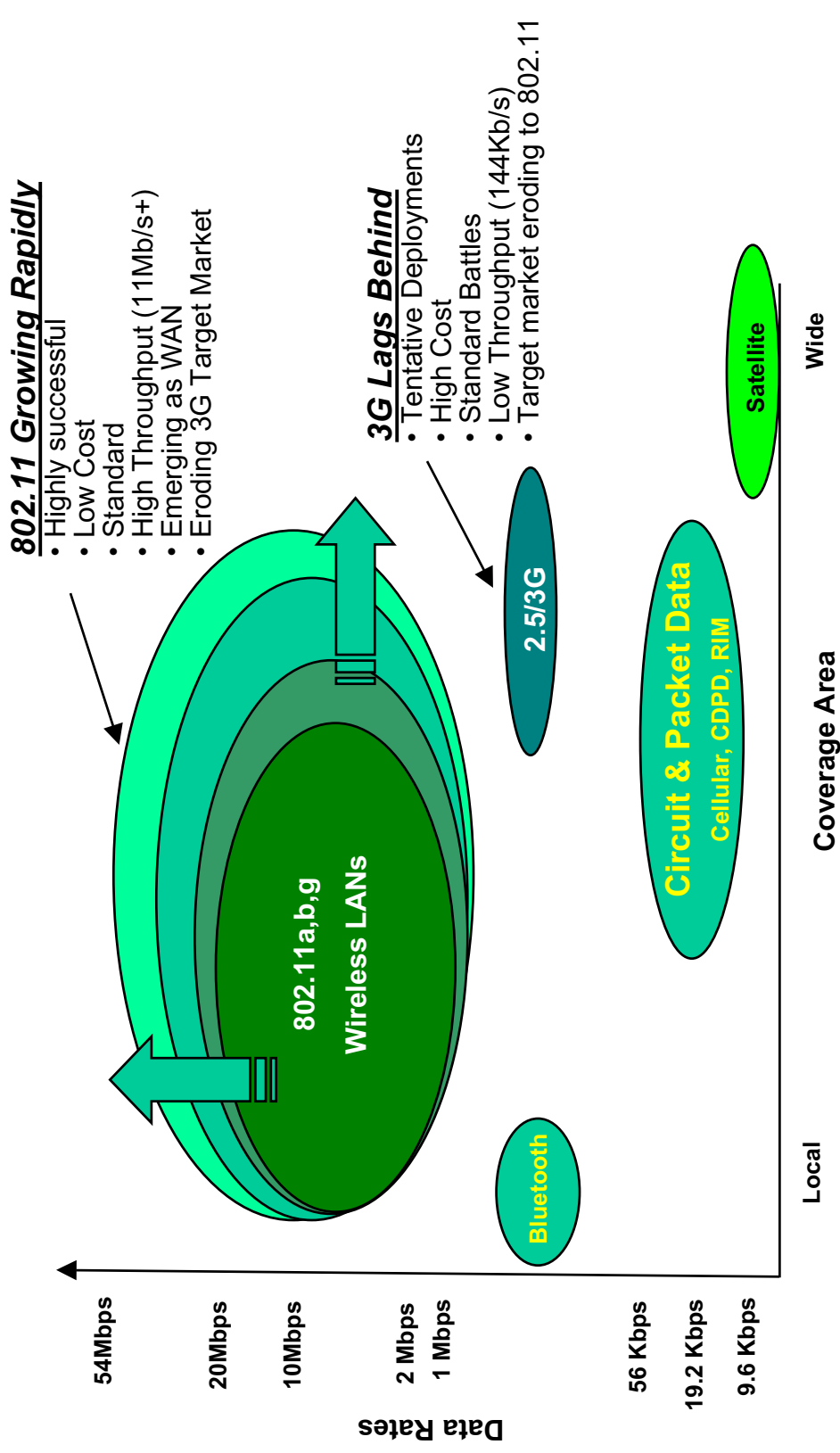
Positive Signs for WLAN Market



Business Week “The grassroots movement is catching on in Corporate America...”

- More organizations using or piloting WLANS. Penetration is 45% today versus 8% in 2001. 75% projected by end of 2003*
- Hotspots sprouting, gaining user interest
- Notebooks increasingly becoming WLAN capable. Will be standard for most notebooks by 2H03
- WLAN prices are dropping rapidly making them even more popular with consumers
- Greater comfort with WLANs due to increasing awareness among customers that security issues are being solved

Wireless Data Landscape



Source: Cisco Systems, RF Solutions

WLAN Adoption

Gartner:

- Nearly 25% of mobile business users had have some 802.11 capabilities by the end of 2002
- There will be 5.4 million WLAN users by 2003
- Currently 30% of large companies have WLAN, expected to grow to 67% of the largest 1,000 companies by end of 2004
- As many as 19 million workers will use WLAN by 2006

IDC:

- 802.11b capability, projected to grow from 835,000 in 2001 to 4.2 million homes by 2004

Synergy Research:

- Sales of WLAN equipment to residential and small businesses grew more than 25 percent in the fourth quarter, to \$225M

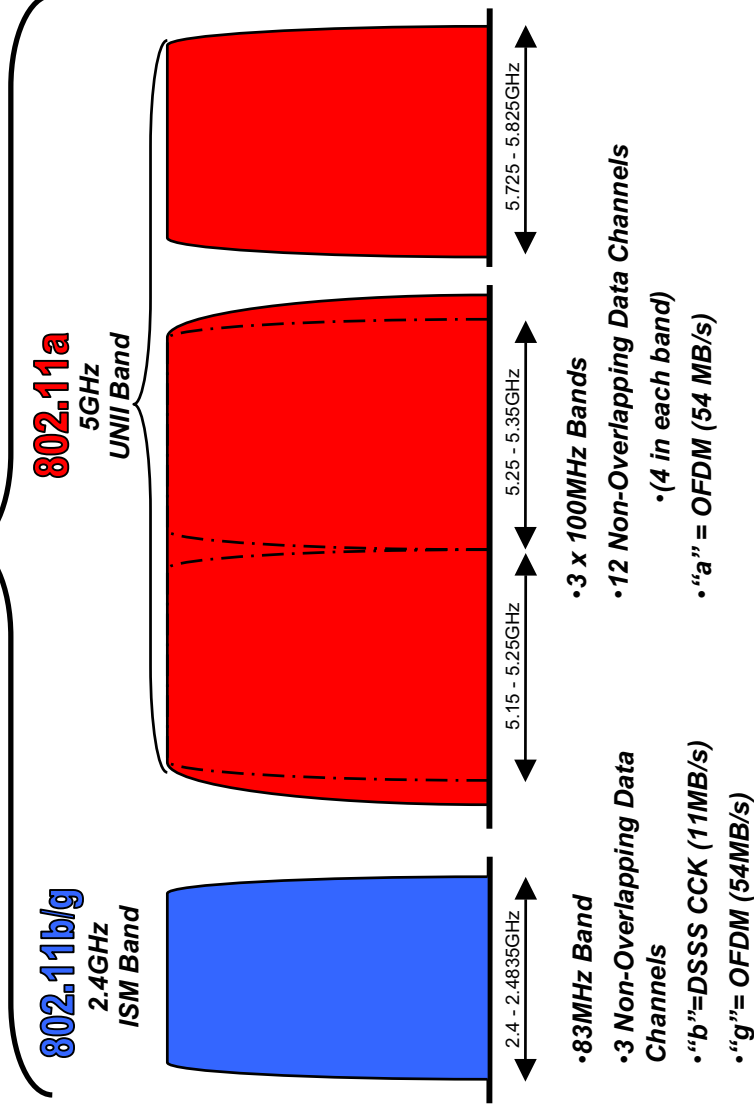
Business Week:

- Starbucks has Wi-Fi in 600 stores, and will be in 4,000 stores by end of 2003
- Over 90% of new laptops will be Wi-Fi ready by 2005, up from 35% by year end 2003

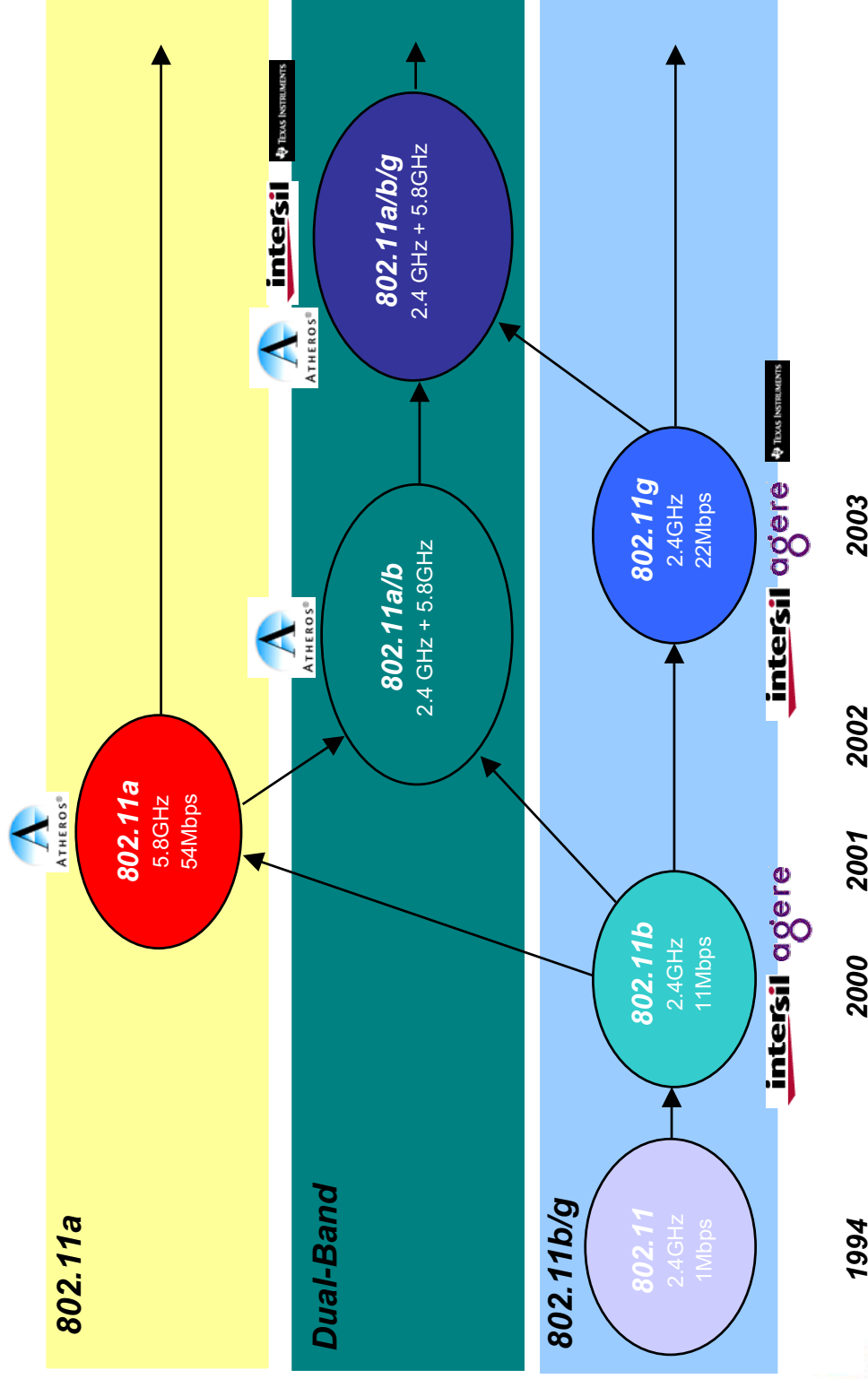
Which band do you like

Dual Band Operation Provides:

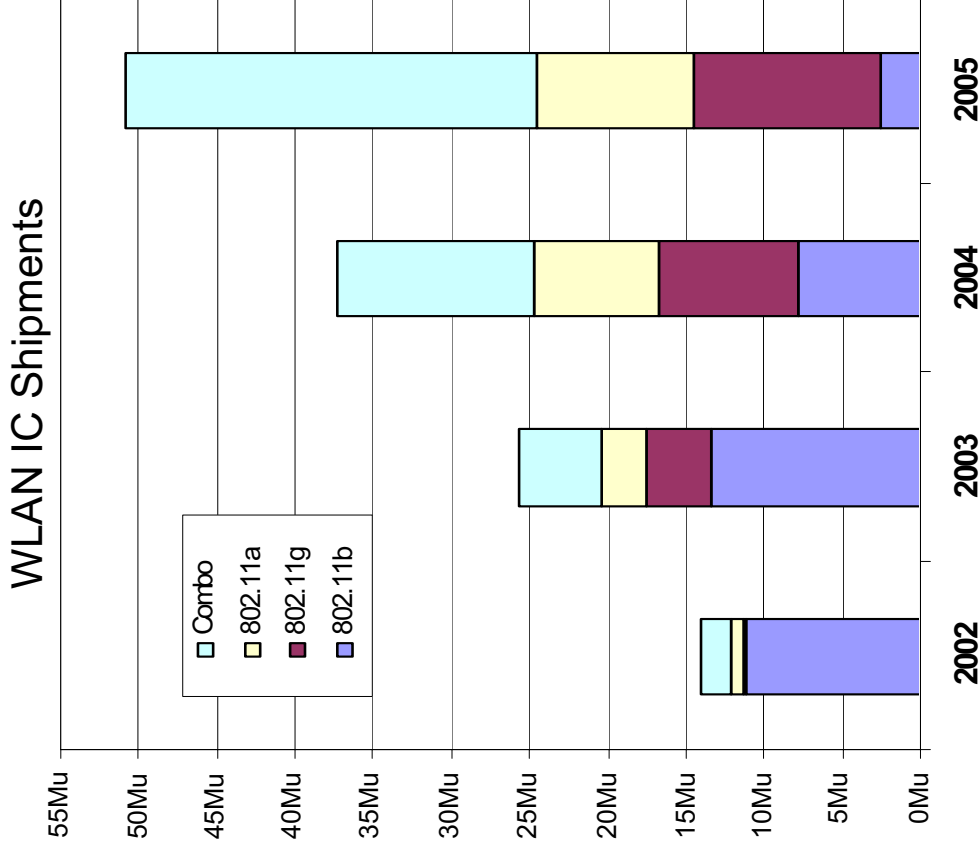
- *Interference Mitigation*
- *Congestion Mitigation*



802.11x market evolution



WLAN Market is Exploding



- Shipments tripled in 2002 and will double in 2003
- 802.11g overtakes 11b, requiring highly linear, more efficient PAs
- Combo adoption accelerates, by 2004 represents more revenue than 802.11b+g

WLAN Hardware Options

PCMCIA cards



CompactFlash



PCI



mini-PCI



USB



Access Points

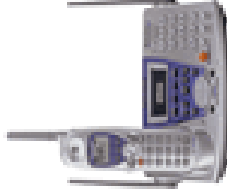
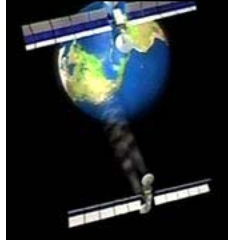


Gateways



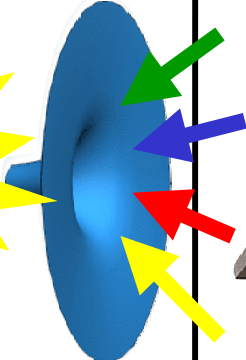
Other Addressable Markets

- Cellular + WLAN
- Telematics
- Set Top Box
- Satellite Radio
- Cordless Phones
- Consumer Electronics



Hot Spots are hot

- Hot spot Industry segments

Brands - End users		
Aggregator - Roaming & Software		
Hot Spot Operators - Networks		
Venues - Locations		

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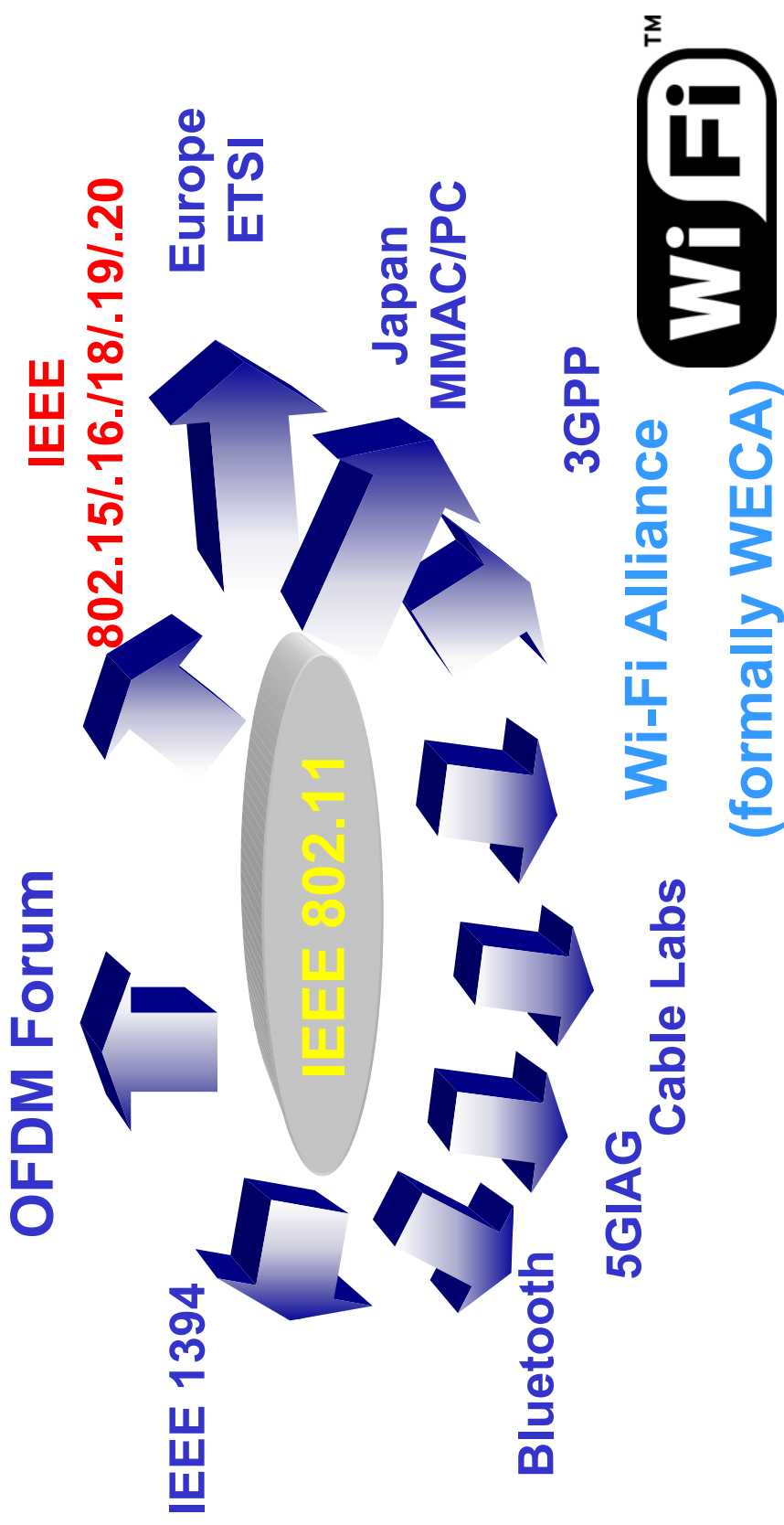
WLAN Standards Summary

Standard	Freq	Phy	Thruput	Range	Std Ratified	Chips Avail	Prod Avail
Bluetooth	2.4G	FHSS	1Mb/s	30ft	Partial 2000	Q201	Limited Vol
802.11b (Wi-Fi)	2.4G	DSSS	11Mb/s	200-300ft	1999	Q101	High Vol
802.11g	2.4G	OFDM	22-54Mb/s	200-300ft	2Q02	4Q02	1Q03
802.11a	5G	OFDM	54Mb/s	100-300ft	1999	4Q01	1Q02
HiperLAN/2	5G	OFDM	54Mb/s	100-150ft	2Q02	3Q02	??

• Current active 802.11 task group projects

Task Group	Project	Target Date to Complete	Key Features
TGE	MAC Enhancements - QoS	July 2004	EDCF, EPCF (Poll Access)
TGG	2.4GHz High Data Rate	July 2003	54Mbps in 2.4GHz
TGF	inter Access Point Protocol	July 2003	AP Mgmt
TGH	802.11a Spectrum Mgmt	Nov 2003	Tx Pwr Control
TGI	Enhanced Security Mechanisms	July 2004	Advance Encryption Standard (AES) Temporal Key Integrity Protocol (TKIP)
TGJ	4.9GHz Japan	July 2004	OFDM operation at 4.9GHz
TGK	Radio Resource Measurement	July 2004	Wireless Network Mgmt
WNG	Wireless Next Generation	N/A	Call for Interest committee Data rates >54Mbps to be TGN in Sept -03
HSTG	High Throughput Study Group	2H - 2006	

IEEE 802.11 Liaisons with other organizations



802.11 New Areas of Interest

- Wireless Next Generation (WNG)
 - WLAN and 3G interworking
 - Mesh Networking
 - Expansion into WAN coverage
 - Telematics
- HTSG (High Throughput Study Group)
 - >54Mbps
 - Innovative architectures
 - MIMO Antennas, and multiple receivers
 - Task Group TgN in September 2003
 - Special Committees
 - Residential – Enterprise Application usage models
 - Channel usage models

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WLAN IC technology choices

- What are the key technology issues?
- What is the right approach – system on a chip (SOC) or system on a package (SOP)?
- What is the right WLAN chip architecture – direct conversion, dual conversion etc.
- Module technology choices
- Which is the right process?
 - Si CMOS, SiGe BiCMOS, GaAs HBT, MESFET, PHEMT
- Single band vs. multiband, 802.11 a/b/g
- Single standard vs. multistandard, 802.11, GSM, GPRS, WCDMA, WiMax

WLAN System and Market Requirements

- Single band migrating to multiband Multimode Operation ie. 802.11b to 802.11g to 802.11a,b,g
- High Performance
 - Long Range - Many Current 802.11a Products Have Low Range at 54 Mbps
 - Low Power Consumption
 - High Data Rates
 - Access Pt. vs. NIC Architectures
 - NIC cards need lower power dissipation than access points
 - Additional Features
 - Bridge Products
 - Small Size
- Low Production Cost
- Flexible Architecture
- Early Market Entry

What are the right WLAN technology choices, SOC or SOP?

System on a chip (SOC) vs System on a package (SOP) tradeoffs

High Performance Dual Band WLANs Require Multiple Processes

- GaAs HBT for PA
- PHEMT for LNA / Switch
- MCM Technology LTCC / Softboard for Integrated Antenna / PA / Switch / LNA
- NIC Card and Access Point May Have Different Needs
- 802.11b Only WLAN Chips Have Easier Specs for SOC

How Much Integration?

- Dependent upon System Architecture / Partitioning
- Higher Integration Lowers Cost (up to a point)
- High Integration Does Not Allow Flexibility
 - Access Point and NIC Cards have different IC needs
 - Bridge Products
 - Multi Antenna
 - Extra Long Range
- Dual Conversion vs. Single Conversion Architectures
- Should PA, LNA Switches be Integrated on the Same Chip
- Integrating High Performance PAs, Tough in CMOS

What is the Right Process Technology for WLANs

- SiGe Bipolar / BiCMOS - Low Cost / High Performance
 - PLL and Digital Functions Are Better Done in CMOS
 - High performance Multi-Band Architectures Are Better Done in SiGe
- Si CMOS / BiCMOS - Very Low Cost / Performance Issues for multiband operation
 - Good for Single Band Architectures and Digital Functions
- GaAs MESFET / HBT - Low to Moderate Cost / High Performance
 - High Performance RF Functions, i.e. LNA, PA switch are better done in GaAs
- What is Best? (lower cost and higher performance)
 - 1) High Performance SiGe Process with High Yields; or
 - 2) Low Performance CMOS Process with Low Yields

RFIC Technology by Function

Function	BiCMOS	RF CMOS	GaAsFET	GaAsHBT	SiGeHBT	pHEMT
LNA	Good	Good	Very Good	Good	Good	Very Good
Mixers	Good	Good	Very Good	Very Good	Good	Very Good
PA	Fair	Fair	Very Good	Very Good	Fair	Very Good
RF Switch	Fair	Fair	Very Good	Poor	Poor	Very Good
VCO	Very Good	Good	Fair	Good	Good	Fair
PreScalers	Very Good	Very Good	Fair	Good	Good	Fair
Digital Functions	Very Good	Very Good	Fair	Fair	Good	Fair

WLAN Systems Require High Performance

- OFDM Systems Require High Performance
 - High Dynamic Range
 - Significant Back-Off in PAs
 - High Performance LAN and Switches
 - Multiband and Diversity Antennas with Switches
 - Low Phase Noise VCOs
- Si CMOS OK for Single Band b/g but Multiband / High Power Operation Difficult with Si CMOS (Yield Issues)
- GaAs HBT Good for High Efficiency Low Current and Low EVM PAs
- Bottom Line -Multiband WLAN Systems Require High Performance RF with Need for Multiple Process and System on a Package Technology

WLAN technology choice comparison

- Optimum process technology depends on WLAN market / product needs /system architecture

Market	Performance / cost	Technology choices					Transceiver	Integrated Transceiver /PA		
		P-Si CMOS	P-SiGe BiCMOS	P-GaAs HBT	T-Si CMOS	T-SiGe BiCMOS		T/P--Si CMO	T/P-SiGe BiCMC	T/P-GaAs HBT
	Rating									
802.11 b	performance	2	3	5	4	5		3.5	4.5	6
802.11 g	performance	1.5	3	5	4	5		3	4.5	6
802.11 a	performance	1	3	5	3.5	5		2.5	4.5	6
802.11 a/b/g	performance	1	3	5	2	5		1.5	4.5	6
802.11b	cost	1	1	1	1	1.2		1.2	1.2	3
802.11g	cost	1.5	1.2	1.4	1.5	1.4		1.6	1.4	3
802.11a	cost	2.5	2	1.8	1.8	1.8		2.4	2	3.5
802.11a/b/g	cost	4	2.5	2	3	2		4	2.2	4
		optimum technology choice for performance /cost								

Key to a Successful Radio

- Integrate as much as possible on a chip without lowering yields
- Time to Market - Time Is Your Enemy, MCM Allows One to Meet the Tough Specs - Quickly
- MCM approach is better if the system requires different IC process, many filters and passives (L, C, Rs) outside the chip

Non 802.11 standards based radio applications – mouse, keyboard, etc.

- Applications: PC mouse, keyboard, audio headsets, game controllers
- Requirements
 - Low cost , low power, small size, 1Mbps data rates
- Approach
 - Use Micro Linear ML2724, ML 2722, Single-chip transceivers at 900 or 2.4 GHz transceivers
 - Package radio / baseband / micro controller is a small package
- Benefits – less overhead, lower cost, optimized radio, baseband / processes for the application like PC keyboard, mouse, wireless game controllers etc.
- 802.11 data systems can be too expensive for some low cost data applications

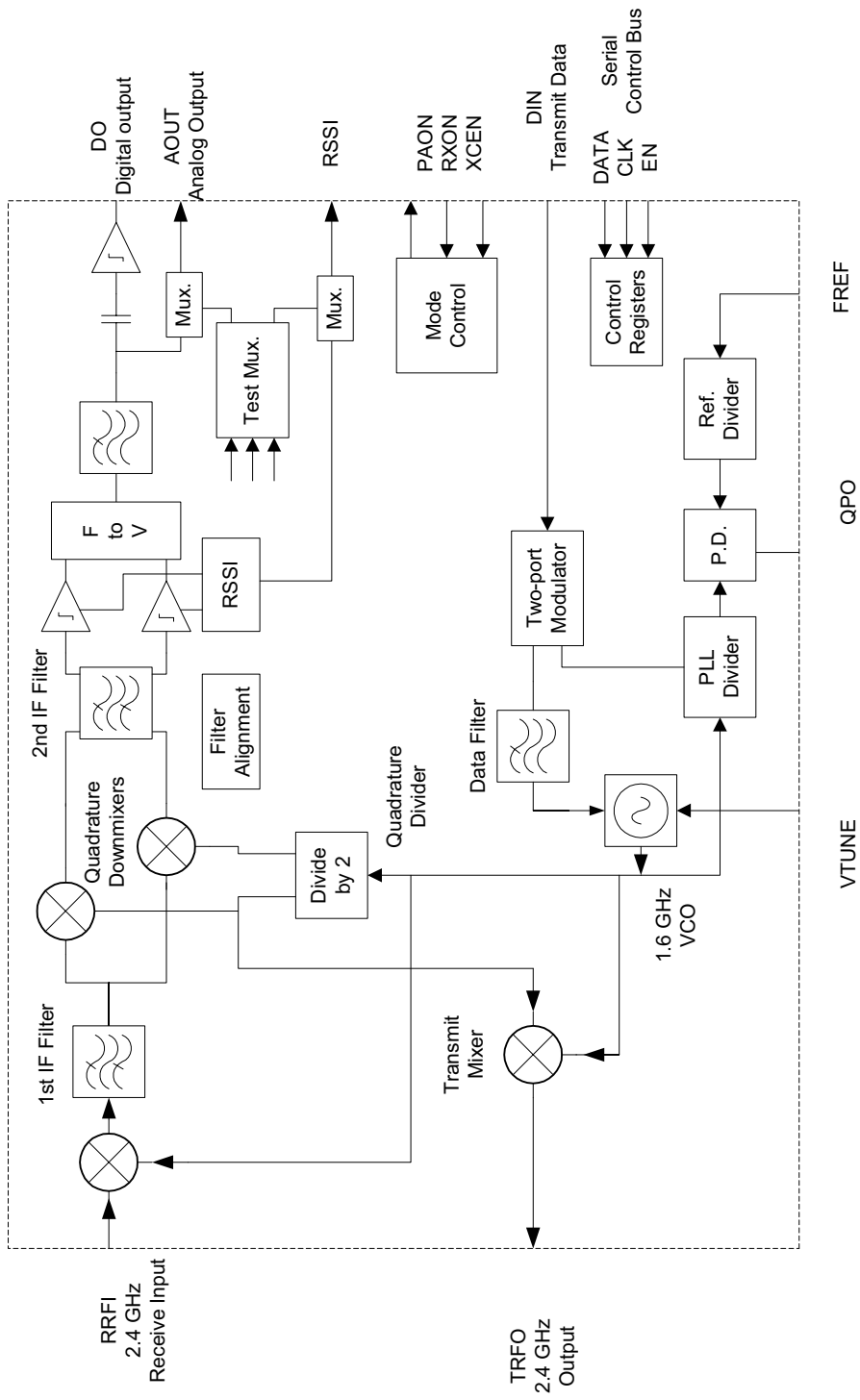


Sony PlayStation 2

Non 802.11 standard based radio solution for data applications

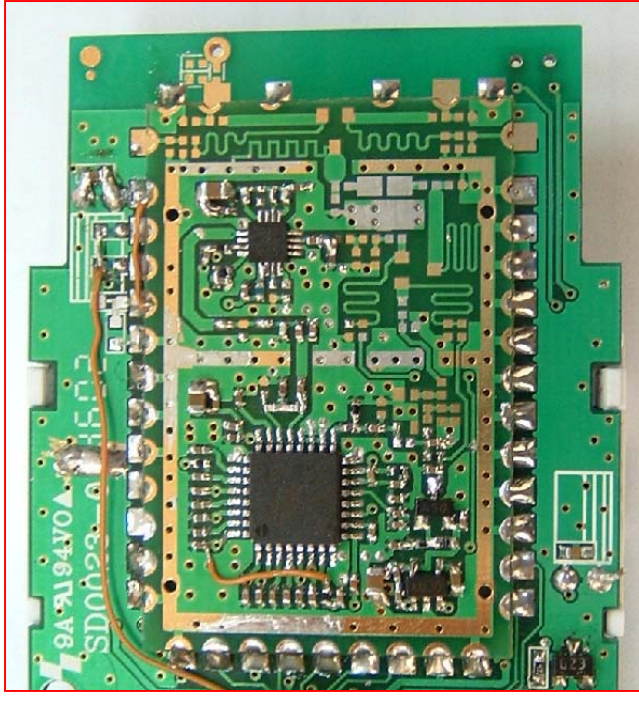
- **ML2724**
 - 2.4GHz single-chip FSK transceiver
 - Double conversion Low IF Architecture
 - Closed-loop direct VCO modulation with on-chip premod filter
 - Automatic self-aligned channel filtering for optimum sensitivity
 - No external SAW filters or tank ckt. needed
 - DIG In - DIG out
 - 1.5 Mbps
 - More than 10 Million 2.4 GHz radios shipped

Micro Linear ML2724 Transceiver

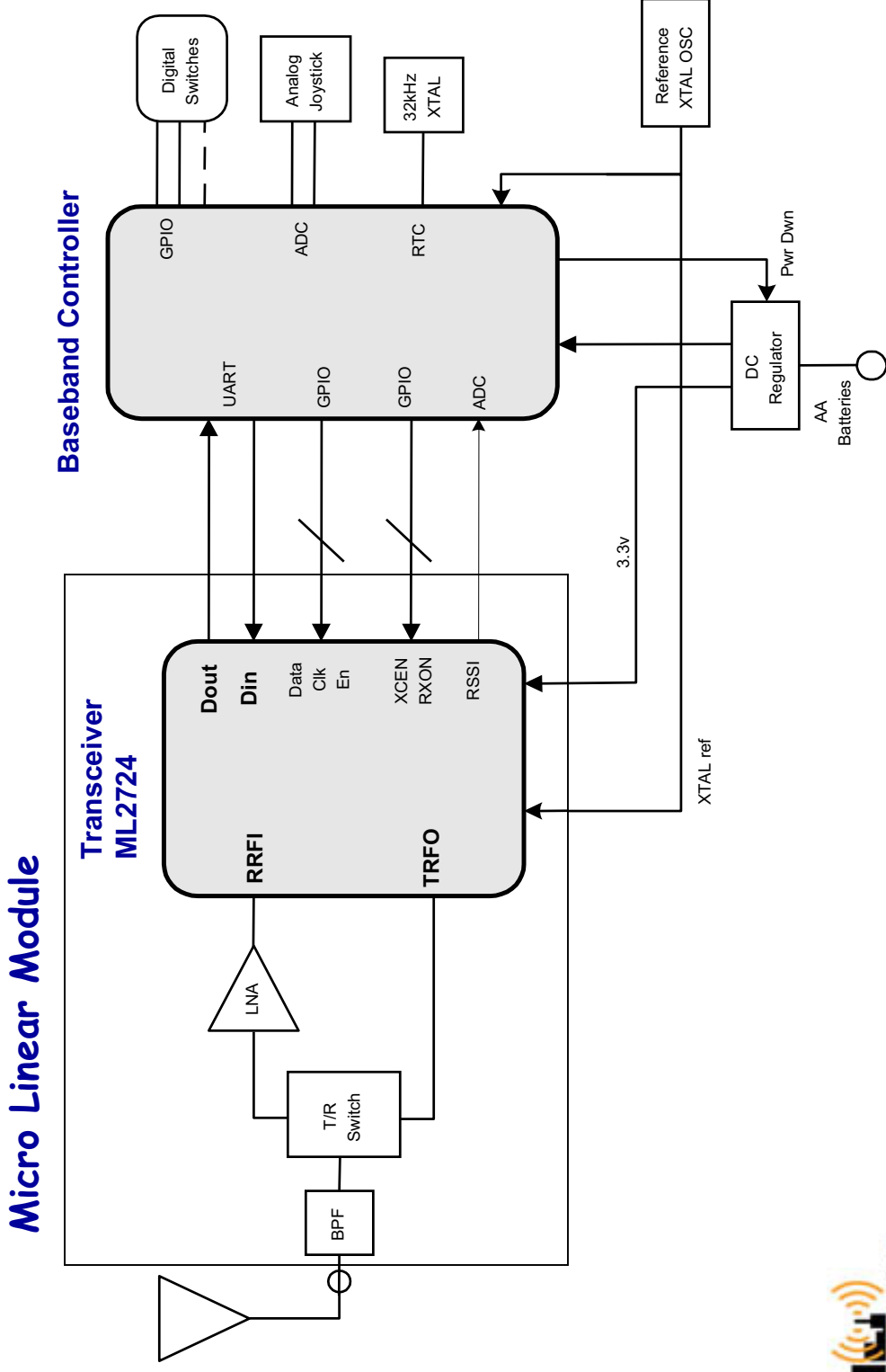


Micro Linear Radio Module

- Total Radio Module Solution
 - Only one ceramic BPF
 - No SAW filters
 - No LC tank circuits
 - 2-layer PCB
 - 27 x 41mm
 - 20 dBm Tx power
 - -95 dBm Rx sensitivity
 - 200 ma Tx current
 - 80 ma Rx current

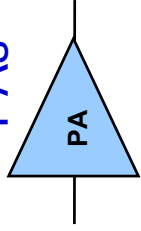


Basic Wireless Controller Block Diagram



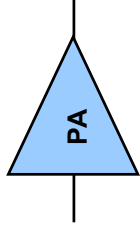
WLAN Front-end Module

PA



power amplifier
- 11a
- 11b/g
- Dual-band

PA Module



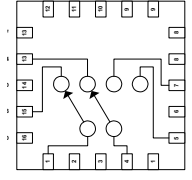
power amplifier
passives / bias

Front-End Module



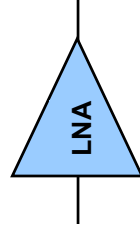
power amplifier
passives / bias
switch / LNA

Switch



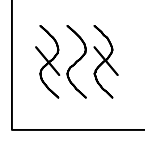
Diversity, Tx/Rx

LNA



- 5 GHz LNA
- Sw / LNA
- PA / LNA

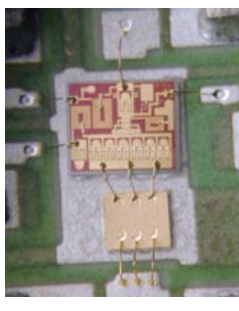
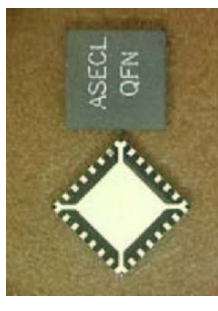
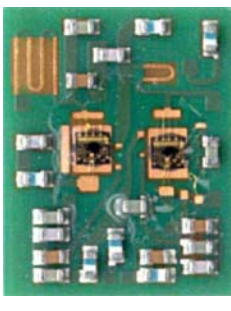
Filters



- BPF
- LPF
- Balun

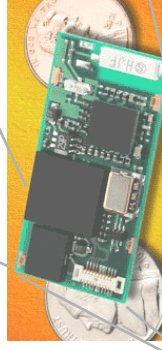
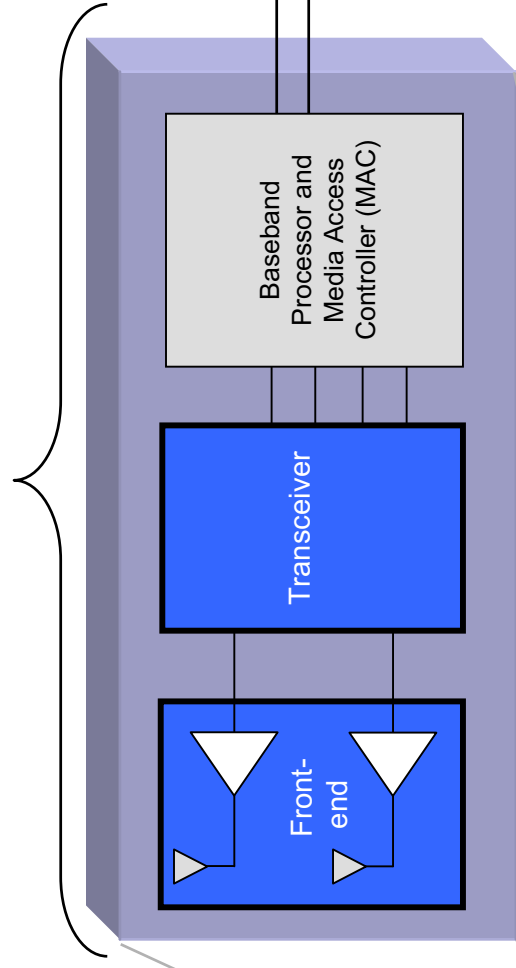
Benefits of MCMs

- MCM allow improved performance and flexibility
 - Pout, gain, functionality, specs etc. can be changed for different customers in the same package
 - Can mix different processes, CMOS, GaAs HBT, LTCC filters, passives
- Quick development time
 - Module development times are about 50% of the IC development times due to faster laminate fab. time
- Simplicity, less parts and ease of use
 - Customers prefer 1 part over 5 or 10 parts
 - Customers with poor RF knowledge can use MCMs easily



WLAN Module

- Single chip 802.11 a/b/g MCM is possible in near future with 2-4 highly integrated chips



- MCMs will play a key role in PDAs, cell phones, small thin notebooks and WLAN SD cards like Sychip WLAN 6060



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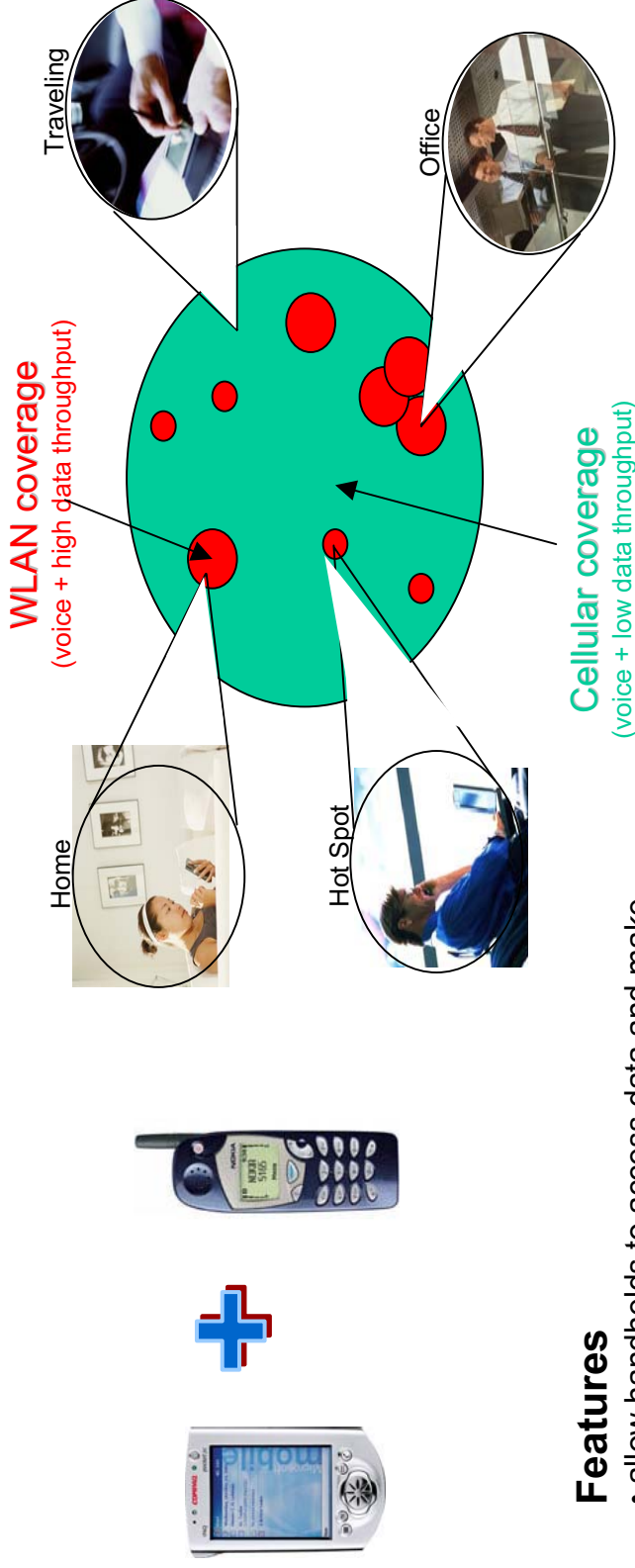
Convergence

- Integrated cellular and Wi-Fi network
 - Wide area coverage for notebooks, PDA, cell phones
- Integrated telephony and Wi-Fi network
 - Lower cost for long distance calls
- Integrated of Bluetooth and Wi-Fi network
 - Wide area coverage and more network options for notebooks, PDA, cell phones

Integrated Cellular / WLAN chipset

- Why does it make sense
 - Lower cost, better performance, ease of use
- Markets for integrated Cellular / WLAN chipset
 - PDA, Cell phones, Notebook PCs
 - 2G, 2.5 G vs. 3G
- Data Rates
 - WLAN - 11 to 54Mbps
 - 2G - 14.4Kbps
 - 3G - 2Mbps, GSM / GPRS / CDMA200 / WCDMA
- Standard
 - 802.11a,b,g and GSM / GPRS / WCDMA
- Coverage
 - WLAN -small area, Hotels, airports, hot spots
 - Cellular - wide metropolitan area

Integrated cellular WLAN chipset



Features

- allow handhelds to access data and make wireless voice calls
- fully compliant with IEEE 802.11a/b WLAN standards
- runs on GSM (Global System for Mobile Communications) and GPRS (General Packet Radio Service) networks

Applications

- voice + WLAN PCMCIA card for notebook or PDA
- Embedded adding WLAN to cell phone
- email
- streaming video
- voice

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WLAN issues

- Limited in building range - up to 300 feet
- Lower data rate at longer distances
- Absence of network management capability to avoid congestion
- Poor Quality of Service
- Significant costs to enhance and expand the WLAN networks
- Interference with other WLAN systems in the area

WLAN issues

- Standards are Evolving
 - Which standard will win 802.11b, g or a/b/g
- Coverage is Spotty
- Security is not reliable
- Network Management costs are high
- Interoperability is limited
- Business models of many startups questionable
 - Can the market sustain more than 70 WLAN startups
- Miscellaneous – Billing, network scalability

Future technology trends

- More integration on chip - single chip CMOS, SiGe 802.11b solution
- Higher integration MCMs
- Multi-band radios
- Multi-standard radios - integration of cellular and WLAN networks
- Active / Multiple antennas, MIMO system, extended range WLAN
- Interference mitigation
- WLAN system optimization

Conclusions

- WLAN market is growing rapidly and the industry shows signs of taking off in a big way
- WLAN technology works well and is cost effective
 - Volume will drive the price down further
 - 802.11 b, g and a/b/g standards well established and improving further with enhancements
- WLAN technology is improving rapidly and is getting integrated with other broadband technologies i.e.. 3G / cellular, Cable TV, DSL, Bluetooth, BWA and will play a key role in wireless last mile solutions