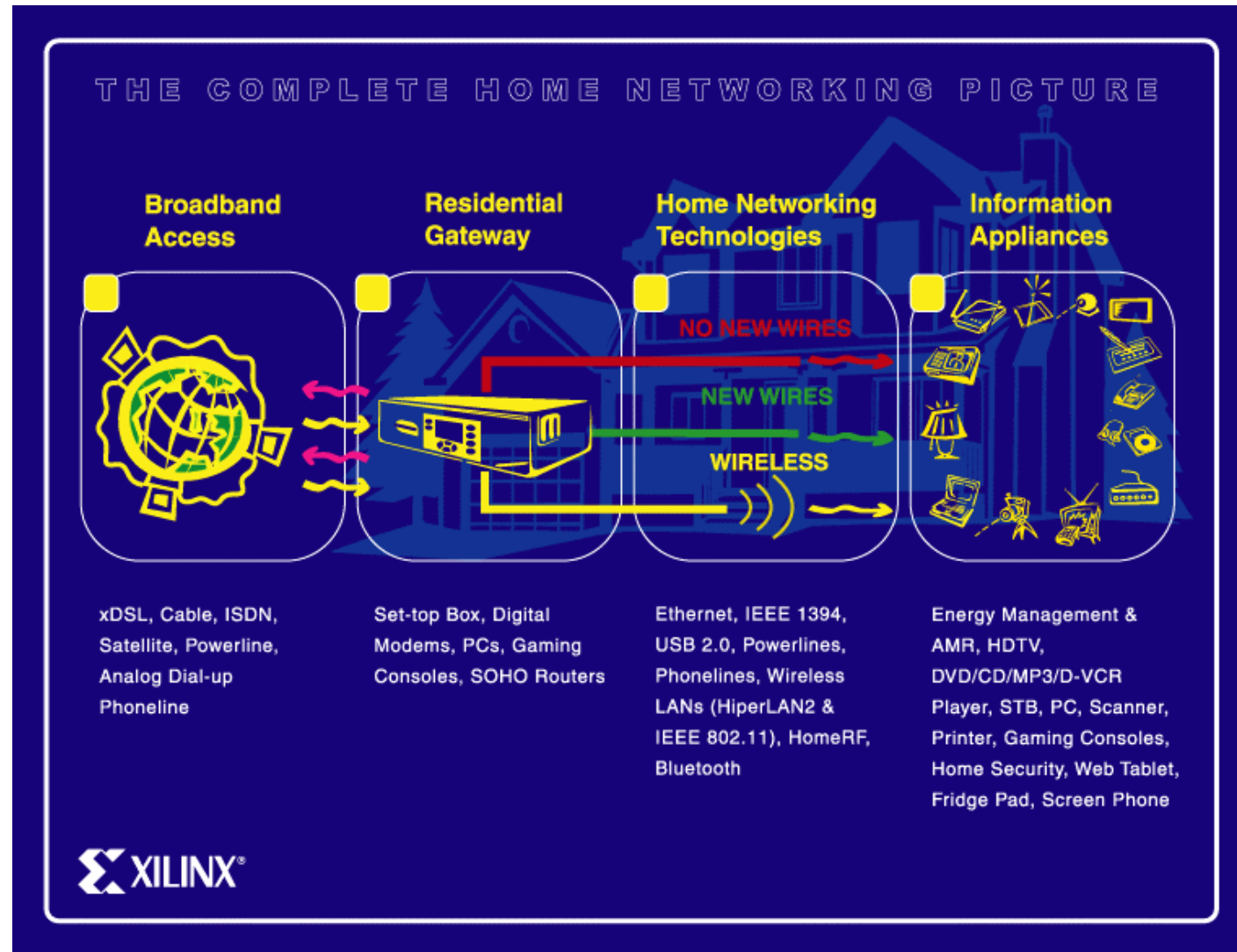# Introduction

The Coming of the Digital Age

Market Trends - Wireless Home Networking

Introducing Wireless LANs

Applications for Wireless LANs

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Four Aspects to Home Networking

THE COMPLETE HOME NETWORKING PICTURE

Broadband Access

Residential Gateway

Home Networking Technologies

NO NEW WIRES

NEW WIRES

WIRELESS

Information Appliances

xDSL, Cable, ISDN, Satellite, Powerline, Analog Dial-up Phoneline

Set-top Box, Digital Modems, PCs, Gaming Consoles, SOHO Routers

Ethernet, IEEE 1394, USB 2.0, Powerlines, Phonelines, Wireless LANs (HiperLAN2 & IEEE 802.11), HomeRF, Bluetooth

Energy Management & AMR, HDTV, DVD/CD/MP3/D-VCR Player, STB, PC, Scanner, Printer, Gaming Consoles, Home Security, Web Tablet, Fridge Pad, Screen Phone

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Market Requirements and Solutions Available

Market Requirements	Solutions Available
Broadband Access — **High Speed Access for Data, Voice and Video, Always on, Simultaneous Up-link &Down-link Communication, Support Simultaneous and Multi-User Access**	**xDSL, Cable, Powerline, Satellite, Mobile/Wireless**
Residential Gateway — **Provides Access into the Home, Remote Management Access Platform, Bridging between Different Networks, Firewall and Security, E-Services Capabilities**	**Open System Gateway initiative (OSGI), Jini, UPnP, HAVi, DVI**
Home Networking Technologies — **Low Cost, Speed, Mobility, Quality of Service, Security, Reliability, Ubiquity, Ease of Use**	**No new wires (Phonelines, Powerlines), New wires (Ethernet, 1394, USB2.0, Optic Fiber), Wireless (HomeRF, Bluetooth, Wireless LAN)**
Information Application Networks — **Digital electronics with advanced computational capabilities that add more value and convenience when networked**	**Digital TV, HDTV, set-top box, internet screen phones, digital VCR, gaming consoles, MP3 players, cordless phones, security systems, utility meters, PCs, web pads & terminals, PDAs, digital cameras, auto PCs etc.**

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Home Networking Technologies

Different Strokes for Different Folks

	Home Automation	Entertainment	Information	Personal Communications	Communication
Devices	- Home appliances - Security/safety systems - Utility meters	- TV sets - Set-top boxes - DVD Players - Game consoles - VCRs - MP3 Players	- PCs - Screen phones - Printers - Modems - Routers - Hubs - Scanners	- Mobile phones - Smart phones - Handheld - Laptop - Pagers	- Corded/Cordless telephones - Fax machines
Content	Information on home processes, house environment, remote diagnostics and technical support	Rich multimedia content, electronic programming guides, impulse purchases	Discrete information on external world, shopping for household goods	Information used on the move or requiring instant action: travel, weather, local services, stock market	Information on how to reach people in time and space
Usage Pattern	Communal	Communal	Individual Shared	Individual Personal	Communal or Individual Shared
Connection to Outside World	- Power line - POTS	- Cable - DBS	- Cable modem - ADSL - POTS, ISDN	- GSM - Infrared	- POTS
Practical Networking Technology	- CEBus - X-10 - LONWorks	- IEEE 1394 (Fire Wire)	- HomeRF - HomePNA - Ethernet	- Infrared - Bluetooth	- POTS - DECT - 900MHz, 2.4GHz

Home appliances have different content, functionality, applications, and require different interconnection technologies

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The Coming of Wireless Home Networking

- ◆ Home networking solutions demand
  - — No new additional wires or phone jacks
  - — Interoperability
    - – Compliment phoneline-based home network solutions
  - — Convenience
    - – Simple to install
    - – Easy-to-use
  - — Economical: Low cost
  - — Performance
    - – Bandwidth to support common home networking applications
  - — Secure
  - — Big industry & consortium support (Bluetooth, IEEE, H2GF)

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Why Go Wireless?

- ◆ Provide core home networking capabilities
  - — Multiple PC users share Internet access, printers, files, drives & participate in multi-player games
  - — Internet access - anywhere in & around the home

- ◆ Share wireless voice & data

- ◆ Review incoming messages

- ◆ Activate other home electronic systems by voice

- ◆ Needed in countries where phone lines cannot be used

Key Drivers: Portability & "No New Wires"

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Wireless Home Networking Solutions - Pros & Cons

- Pros
  - Flexibility & mobility
  - Broad geography support at specific frequency
  - Can compliment a wired network with bridging

- Cons
  - Relatively expensive
  - Distance limits & wall attenuation (150ft barrier)
  - Security must be addressed
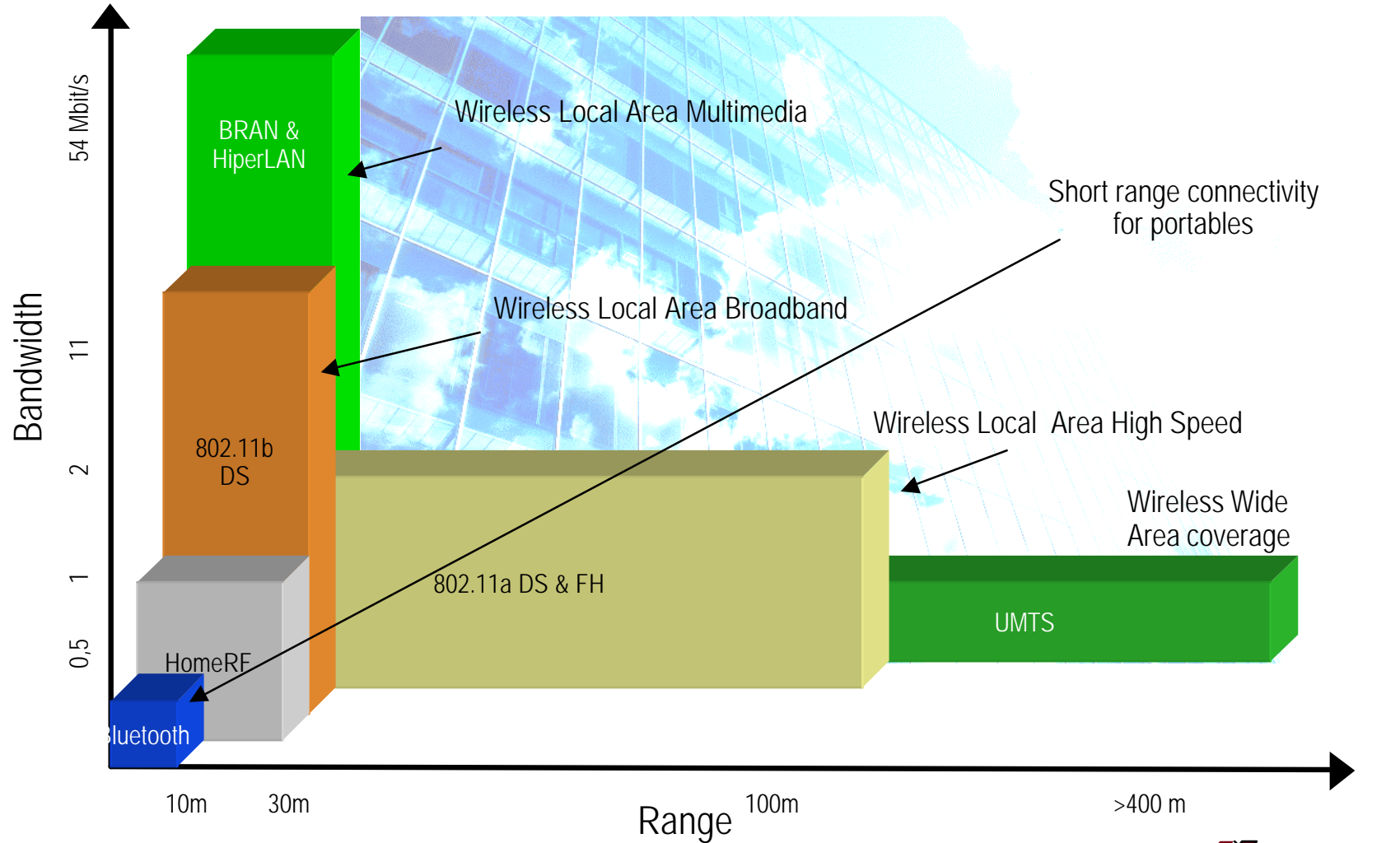 - Performance
    - Prone to narrowband interference

What is a Good Wireless Home Networking Solution?

◆ Powerful
  — Similar capabilities of a typical office network
  — Simultaneous sharing of Internet/broadband access, files & drive, printer/scanner

◆ Simple
  — Simple installation
  — Easy and intuitive use of network

◆ Economical

Wireless Home Networking Technologies

- ◆ Bluetooth & IEEE 802.15
  - — Personal area networking for data & voice communications

- ◆ HomeRF
  - — Home based data & voice transmissions

- ◆ Wireless LANs (local area networks)
  - — High-speed wireless connectivity augmenting wired networks
  - — IEEE 802.11 (a & b variations)
    - – a - 5GHz standard based on OFDM
    - – b - 2.4GHz standard based on Ethernet
  - — HiperLAN & HiperLAN2
    - – 5GHz standard based on OFDM

Wireless Technologies in Home Networking

Bandwidth

54 Mbit/s — BRAN & HiperLAN

11

2 — 802.11b DS

1

0,5 — HomeRF

Bluetooth

Range — 10m · 30m · 100m · >400 m

Wireless Local Area Multimedia

Wireless Local Area Broadband

Short range connectivity for portables

Wireless Local Area High Speed

802.11a DS & FH

Wireless Wide Area coverage

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Cutting the Wires

Technology	Physical Layer	Media Access Control Method	Raw Physical-Layer throughput (Mbits/sec)	Product Availability
IEEE 802.11	Frequency Hopping Spread Spectrum (FHSS) or Direct Sequence Spread Spectrum (DSSS)	Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA)	1 or 2	Now
IEEE 802.11b	Complimentary code keying DSSS	CSMA/CA	11	Now
IEEE 802.11a	Orthogonal Frequency Division Multiplexing (OFMD)	CSMA/CA	54	2001
HiperLAN1	Gaussian Minimum Shift Keying (GMSK)	Three-phase priority driven	23.5	2000
HiperLAN2	OFMD	Cenetral resource control, Time Division Multiple Access (TDMA)	54	2001
OpenAir	FHSS	CSMA/CA	1.6	Now
Wideband OpenAir	FHSS	CSMA/CA	10	2000
HomeRF	FHSS	CSMA/CA	1	Now
Wideband HomeRF	FHSS	CSMA/CA	10	2000
Bluetooth	FHSS	Cenetral resource control, TDMA	1	2000

Variety of Technologies in the Wireless Connectivity Market

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Introducing Wireless LANs

Wireless LANs Provide...

- ◆ Flexible data communication systems
  - — Implemented as an extension to the wired networks (LAN)
    - – Reliance on networking in business & meteoric growth of the Internet & online services are strong testimonies to the benefits of shared data & shared resources
  - — Minimizes the need for wired connections
    - – Users can access shared information without looking for a place to plug in
    - – Network managers can set up or augment networks without installing or moving wires

- ◆ Electromagnetic waves (radio or infrared) are used to transmit & receive data over the air

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Wireless LANs Are Quickly Gaining Popularity

- ◆ Combines data connectivity with user mobility
  - — Provides general purpose connectivity alternative for a broad range of business customers

- ◆ Strong popularity in vertical markets
  - — Health-care, retail, manufacturing, warehousing, academia
  - — Productivity gains are realized by using hand-held terminals & notebook PCs to transmit real-time information to centralized hosts for processing

- ◆ Worldwide wireless LAN market
  - — More than $2 billion revenues by year 2000 *
  - — $2 billion WLAN annual revenues by year 2002 **

Source: * Business Research Group, ** - HiperLAN2 Global Forum

LANScape
Wireless LAN Market Drivers

◆ Product pricing

— Low product prices make wireless LANs a more cost-effective proposition

— Adapters for office products are as low as $200 & half of that for home versions

– Apple's IEEE 802.11b card lists for $99

◆ Standards

— Official or industry consortiums are driving the market

◆ Large networking giants

— Industry leaders like Cisco Systems, Nortel Networks, Nokia & Ericsson are all in the game

LANScape
Wireless LAN Market Drivers

- ◆ Telecommuters

- ◆ Home use
  - — Sharing peripherals & broadband access/Internet are the killer applications

- ◆ Increasing number of users are standardizing on laptops as their only computer
  - — Makes mobile connectivity highly desirable

- ◆ Millions of cell phones will soon become Internet-enabled
  - — Users will want to link up to laptops, hands-free kits in cars & LAN access points

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Differences Between WLANs & Other Wireless Technologies

	Wireless Local Area Network (WLAN)	LAN-LAN Bridge	Wireless Wide Area Network (WWAN)	Wireless Metropolitan Area Network (WMAN)	Wireless Personal Area Network (WPAN)
Coverage Area	In building or campus	Building to building	National	Metropolitan Area	A few feet
Function	Extension or Alternate to Wired LAN	Alternate to Wired Connection	Extension of LAN	Extension of Wired LAN	Alternate to Cable
User Fee	No	No	Yes	Yes	No
Typical Throughput	1-11Mbps	2-100Mbps	1-32Kbps	10-100Kbps	0.1-4Mbps

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Wireless Home Networking Technology Comparison

- Wireless LAN, HomeRF & Bluetooth technologies vary in data rate, range, frequency & marketplace aimed for

Technology		Standards Body /Proponent	PHY Layer	Data Rate	Range (meters)	Frequency (GHz)	Technology Aimed For
Wireless LAN	IEEE 802.11a	IEEE	OFDM	40	TBD	5	Office Environments
	IEEE 802.11b	IEEE	DSSS	11	100	2.4	
	HiperLAN2	HiperLAN2 Global Forum	OFDM	54	150	5	
HomeRF	SWAP 1.1	HomeRF Working Group	FHSS	1.6	50	2.4	Home Space
	HomeRF (next generation)	HomeRF Working Group	FHSS	10	50	2.4	
Bluetooth	IEEE 802.15 (Bluetooth)	Bluetooth SIG	FHSS	1	10	2.4	Consumer, short-range wireless personal area network communication
	IEEE 802.15 (high-rate)	Bluetooth SIG	FHSS	2+	TBD	2.4/5	

DSSS- Direct Sequence Spread Spectrum, FHSS - Frequency Hopping Spread Spectrum, OFDM - Orthogonal Frequency Division Multiplexing

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WLANs in the Real World

- ◆ Frequently augment rather than replace wired networks
  - — Provide the final few meters of connectivity between a wired network (LAN) & the mobile user

- ◆ Wireless LANs provide productivity, convenience & cost advantages over traditional wired networks
  - — Mobility improves productivity & service
  - — Installation speed & simplicity
  - — Installation flexibility
  - — Reduced cost-of-ownership
  - — Scalability

Real-Life Applications of WLANs

- ◆ Increased productivity for doctors & nurses in hospitals
  - — Patient information can be delivered instantly using hand-held devices or notebook PCs with WLAN capability

- ◆ Consulting and/or audit teams
  - — Consulting, accounting audit teams and/or small workgroups increase productivity with quick network setup

- ◆ Library for reference
  - — Students holding class on a campus greensward access the Internet to consult the catalog of the Library of Congress

Real-Life Applications of WLANs

- ◆ Information technology/network management
  - — Network managers in dynamic environments minimize the overhead caused by moves, extensions to networks & other changes with WLANs
  - — Network managers installing networked computers in older buildings find that WLANs are a cost-effective network infrastructure solution
  - — Trade show & branch office workers minimize setup requirements by installing pre-configured WLANs needing no local MIS support
  - — Network managers implement WLANs to provide backup for mission-critical applications running on wired networks

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Real-Life Applications of WLANs

- ◆ Training sites
  - — Employees at corporations & students at universities use wireless connectivity for easy information access, information exchanges and learning

- ◆ Industrial parks, industries and factories
  - — Warehouse workers use WLANs to exchange information with central databases, thereby increasing productivity

- ◆ Critical decision making
  - — Senior executives in meetings make quicker & better decisions because they have real-time information at their fingertips

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Challenges and Constraints

- ◆ Frequency allocation
  - — Wireless networks require that all users operate on a common frequency band
  - — Frequency bands for particular uses are allocated & licensed in each country

- ◆ Reliability of the communications channel
  - — Measured in average BER - bit error rate
    - – Packetized voice cannot have packet loss rates in excess of order of 10^{-2}
    - – For uncoded data, a BER of 10^{-5} is regarded acceptable
  - — Automated repeat request (ARQ) and forward error correction (FEC) are used to increase reliability

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Challenges and Constraints

◆ Security

— Wired networks can have a physically secure transmission medium

– Access to the network is easily controlled

— Wireless network is more difficult to secure

– Since the transmission medium is open to anyone within the geographical range of a transmitter

— Data privacy is accomplished over a radio medium using encryption & authentication

– Encryption comes at increased cost and decreased performance

Challenges and Constraints

- ◆ Security - Encryption
  - — Intended to provide a level of security comparable to that of a wired LAN
  - — In IEEE 802.11 the Wired Equivalent Privacy (WEP) feature uses the RC4 PRNG algorithm from RSA Data Security
  - — The WEP algorithm was intended to be
    - – Reasonably strong
    - – Self-synchronizing
    - – Computationally efficient
    - – Exportable
    - – Optional
  - — Encryption comes at increased cost & decreased performance

Challenges and Constraints

◆ Security - Authentication

— Means by which one station is verified to have authorization to communicate with a second station in a given coverage area

— In the infrastructure mode, authentication is established between an access point (AP) and each station

— Can be either Open System or Shared Key

– In an Open System, any STA may request authentication

– The STA receiving the request may grant authentication to any request, or only those from stations on a user-defined list

– In a Shared Key system, only stations which possess a secret encrypted key can be authenticated

– Shared Key authentication is available only to systems having the optional encryption capability

Challenges and Constraints

◆ Interference

— Interference in wireless communications may be caused by simultaneous transmissions, i.e., collisions, by 2 or more resources sharing the same frequency band

– Collisions are typically the result of multiple stations waiting for the channel to become idle and then begin transmission at the same time - CSMA/CD technique

– Collisions are also caused by the hidden terminal problem

– Where a station believing that the channel is idle begins transmission without successfully detecting the presence of a transmission already in progress

— Interference is also caused by multipath fading

– Characterized by random amplitude and phase fluctuations at the receiver

Challenges and Constraints

- ◆ Throughput
  - — WLANs are currently targeted at data rates between 1-40 Mbps
    - – Physical limitations & limited available bandwidth do not allow the capacity of WLANs to approach that of wired LANs as they ideally should
    - – To support multiple transmissions simultaneously spread spectrum techniques are employed

Challenges and Constraints

- ◆ Power consumption
  - — Wireless devices are portable and meant to be portable and/or mobile and are typically battery powered
    - – Devices connected to a wired network are powered by the local 110V commercial power provided in a building
  - — Very energy efficient devices must be designed
    - – Sleep modes, low-power displays are a must
  - — Timing beacons plays an important role in power management
    - – All station clocks within a BSS are synchronized by periodic transmissions of time stamped beacons
      - – Synchronization is maintained to within 4uSec plus propagation delay
    - – 2 defined power saving modes: awake & sleep

Challenges and Constraints

- ◆ Human safety
  - — Networks should be designed to minimize the power transmitted by network devices
    - – Ongoing research has to confirm whether RF transmissions from radio and cellular phones are linked to human illness
    - – Infrared WLAN systems optical transmitters must be designed to prevent vision impairment

- ◆ Mobility
  - — System designs must accommodate handoff between transmission boundaries & route traffic to mobile users
    - – While wired networks are static the primary advantage of WLANs is freedom of mobility

Customer Considerations for WLANs

- Range & coverage

- Throughput

- Integrity & reliability

- Compatibility with the existing network

- Interoperability of wireless devices

- Interference & coexistence

- Licensing issues

- Simplicity/Ease of use

- Security

- Cost

- Scalability

- Battery life for mobile platforms

- Safety

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