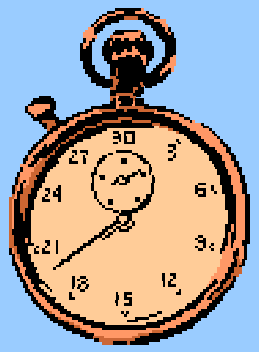
Bluetooth

3G

# What's Right / Wrong With IEEE 802.11?

**IEEE**
Communications Society
February 28, 2002



Bruce Willins
Sr Director Symbol Technologies
Research & Development

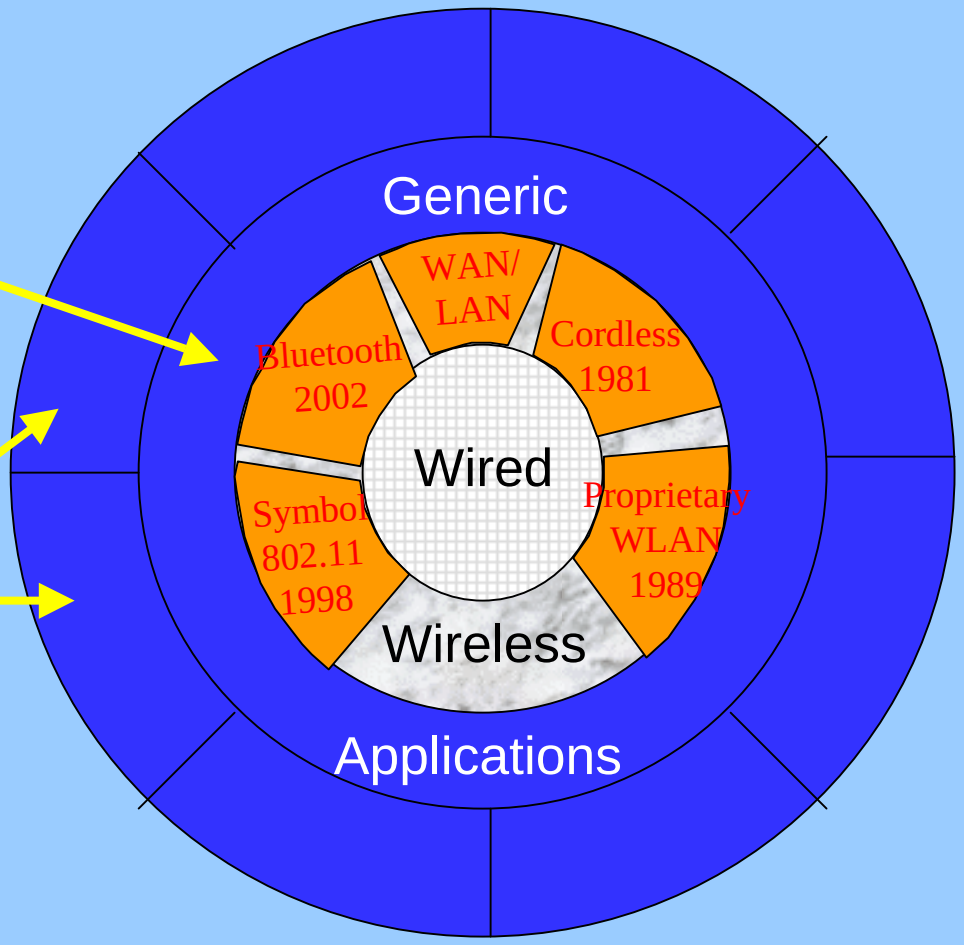
MIT – ThingsThatThink
- Chair: Nicholas Negroponte
- 3G: Doug Grant Analog Devices
- Bluetooth: David Reed

# Role of Wireless LAN

## *Infrastructure Enables Applications*

**Generic Applications**
- Internet/Web Access
- Email
- File & Printer Sharing
- Office Productivity

**Industry-specific Applications**
- Point-of-Sale
- Distribution Logistics
- Inventory Control
- Patient Monitoring
- Curbside Check-in



# Symbol Product Sampling

Internet

Intranet & Extranet

POTS/PSTN

802.11 Access Points

Bluetooth
GSM
CDPD
GPRS

Scanners

Imagers

Data Terminals

Vehicle Terminals

Wearables

H323 VoIP Handsets

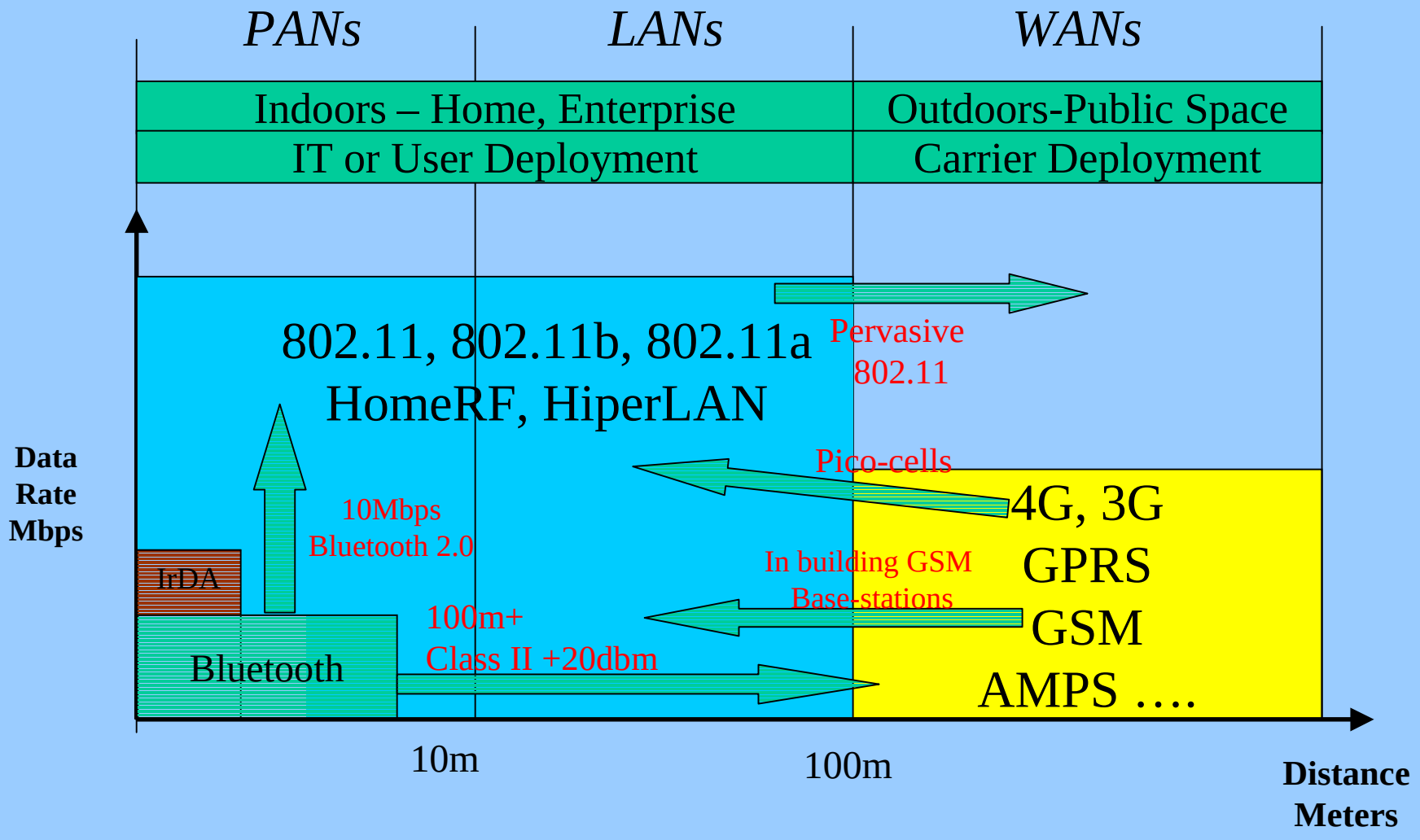
Voice/Data Terminals

# 802.11 The Good, The Bad, The Ugly

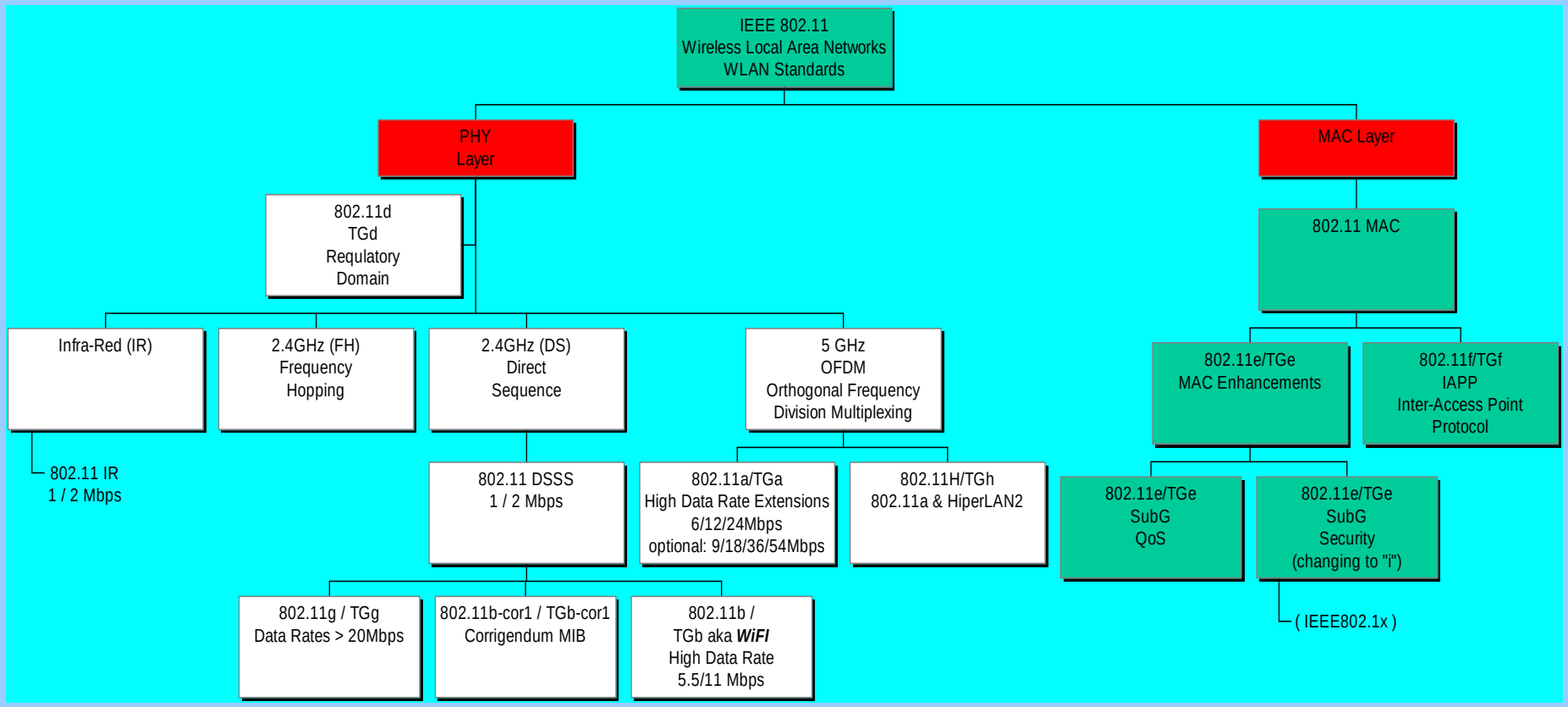

- The Good
  - Technology Foundation: What it is, where it fits, things done well
  - Interoperability
  - Commoditization
  - Market Success
  - Future Trends
- The Bad: Room For Improvement
  - Security
  - FH & DSSS Waveform Confusion
  - Preamble Issues In Rate Scaling
- The Ugly: ISM

# Generalized Models Are Crumbling

## GET OVER IT

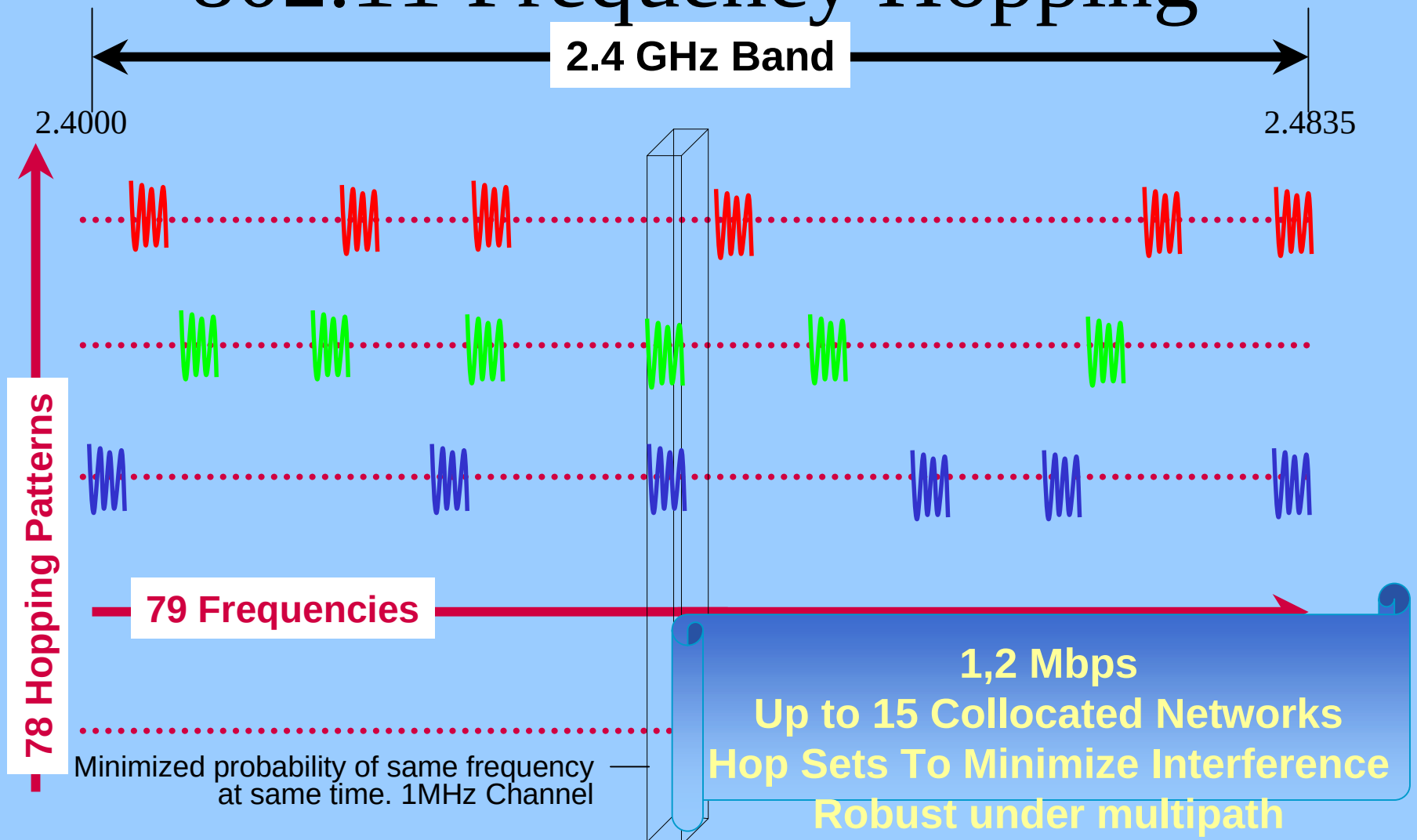


# What Is IEEE802.11?



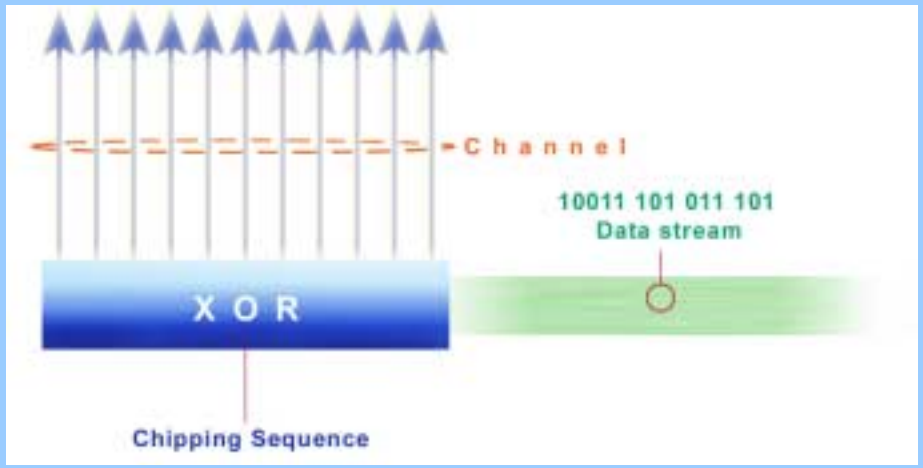

First 802.11 Standard Approved 1997

# 802.11 Frequency Hopping



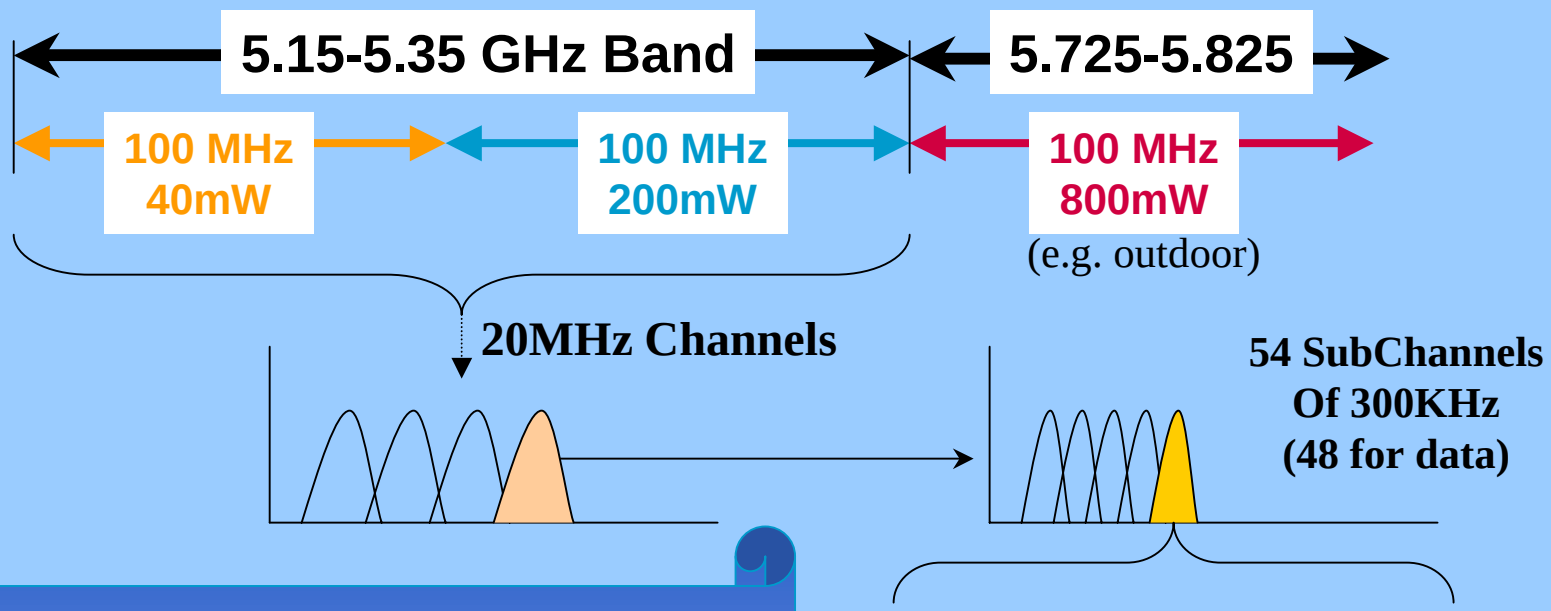

**1,2 Mbps**
**Up to 15 Collocated Networks**
**Hop Sets To Minimize Interference**
**Robust under multipath**

# 802.11/802.11b Direct Sequence


1, 2, 5.5, 11Mbs, +
3 x 30MHz Channels

# 802.11a Orthogonal Frequency Division Multiplexing(OFDM)



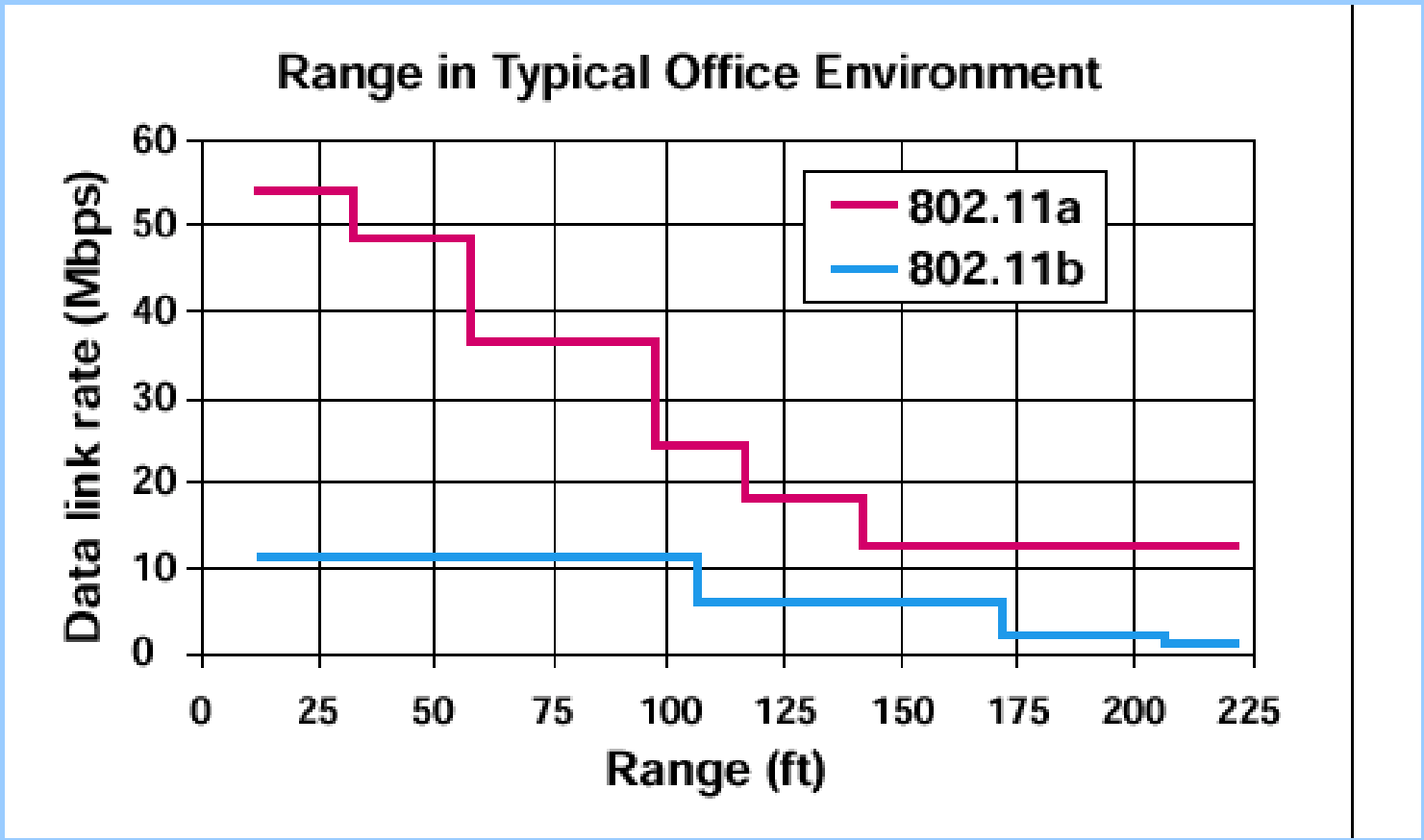

**U-NII - Relatively Clean (for now)**
**12 Non-Overlapping Channels-US**
**Spectrum Issues In Europe & Japan**
**Robust Multipath Performance**

**BPSK-125Kbps => 6Mbps**
**QPSK-250Kbps => 12Mbps**
**16QAM-500Kbps=> 24Mbps**

***Optional: 36,48,54 (64QAM)Mbps***

***Proprietary: 72Mbps+***

# 802.11a Claims




* Atheros Communications, Intel Corporation, “802.11a Scalable 5GHz Wireless LAN”

# Wireless Proliferation

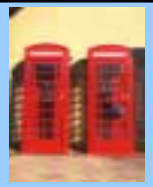
## Enterprise/MAN

Mobile Warrior

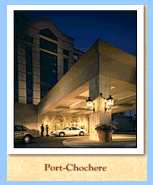
Office/Campus

Home

## Public Space



Public Hot Spots




Hotels

Eg. Hilton
Marriott
Sheraton
Qual Inn
La Quinta
……

Airports

Eg. BOS
LAX
LGA
MIA
SFO
SEA
STL
ORD…..

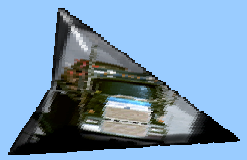
Convention Centers

Restaurants

## Manufacturing /Supply Chain

Manufacturing

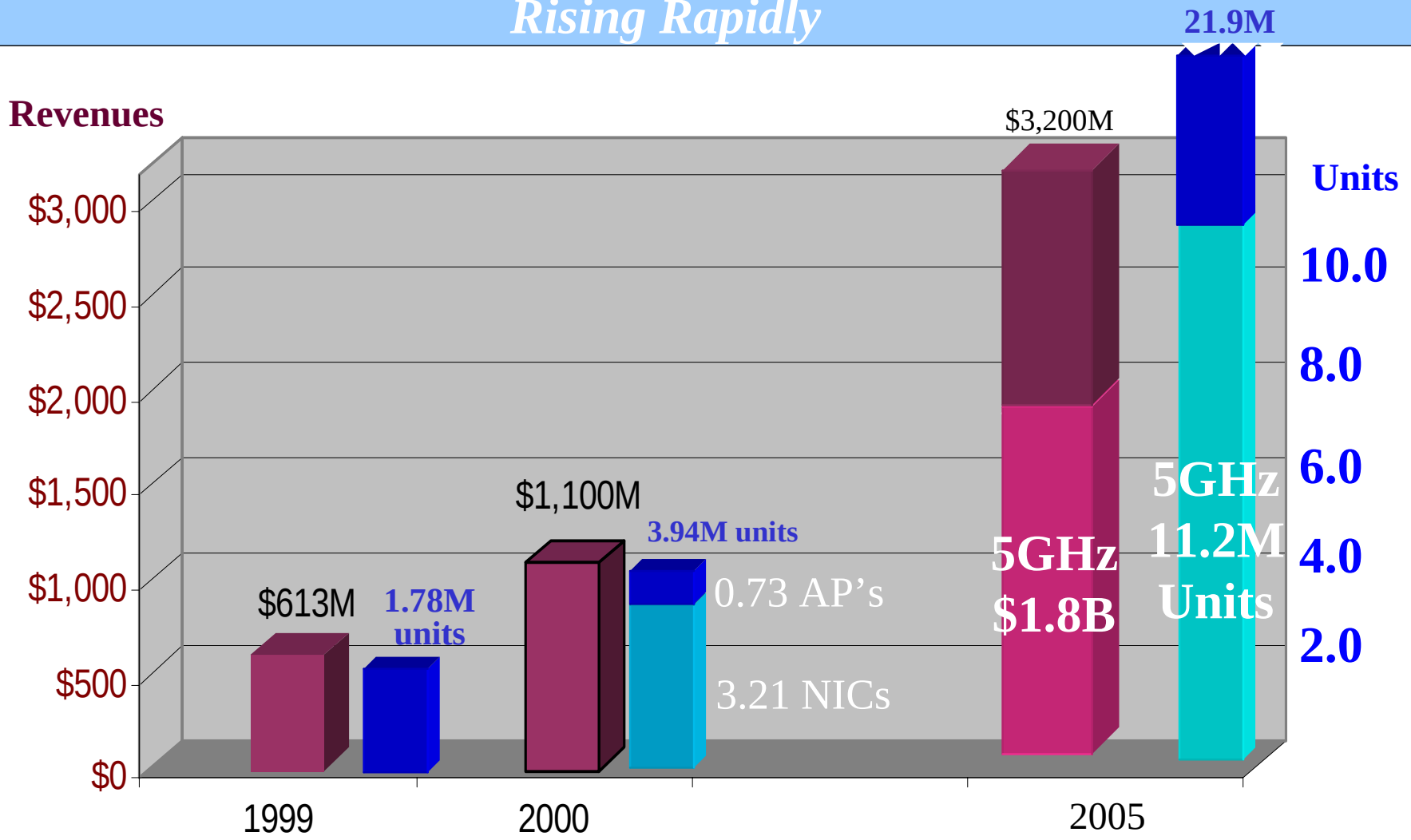
Distribution



Transportation

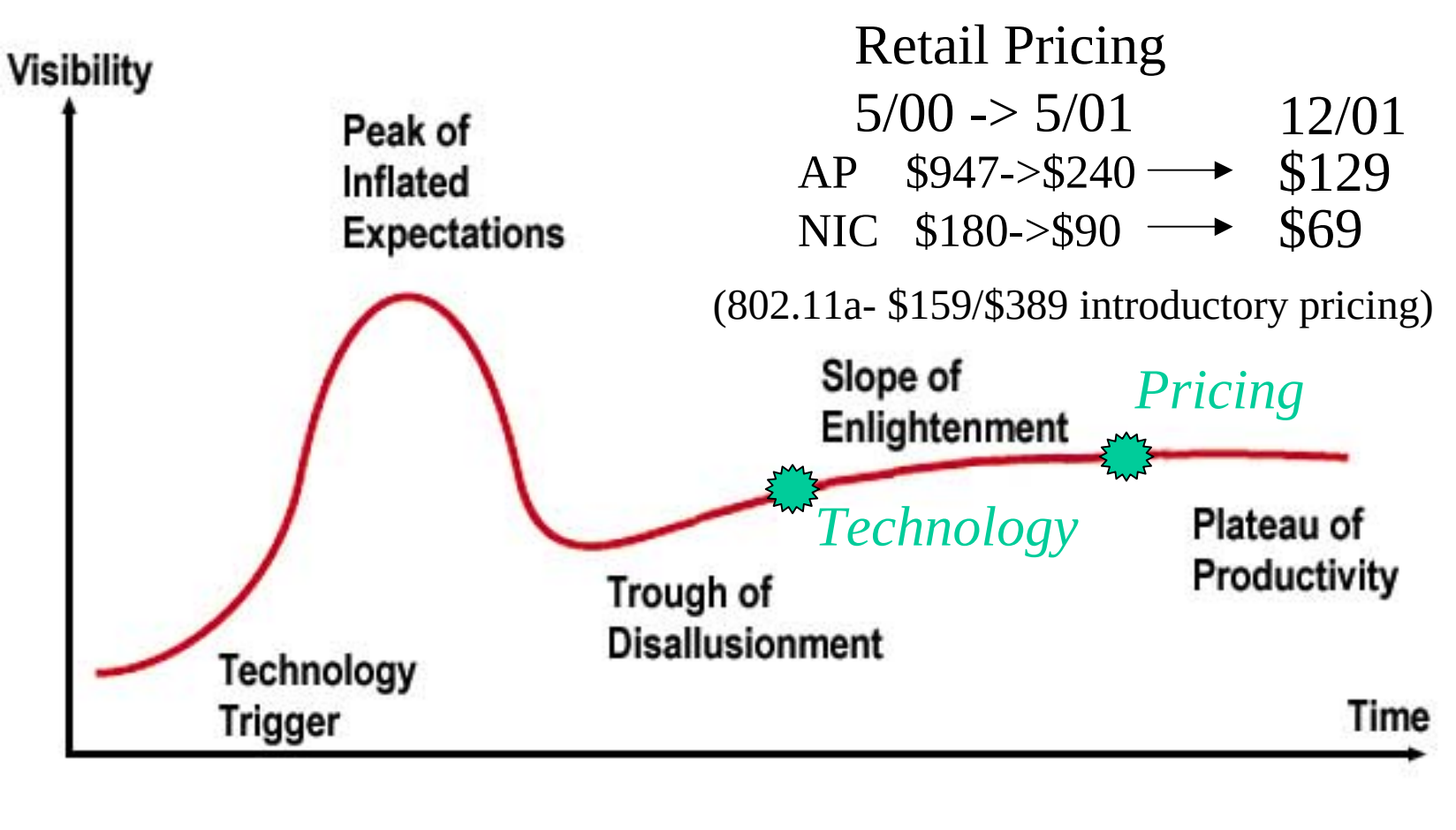
Dealers

# *WLAN/PAN Revenue & Unit Growth Rising Rapidly*




Based On: IDC Wireless LAN Market Forecast Update, 2000-2005, April 2001
"5GHz – consists of 802.11a & HiperLAN

# Pricing Leading Adoption




Gartner Group Technology Hype Cycle

# Several Junctures Along The Way

*2000* *Mid 2001* *Early 2002*

FH

IR

GSM

Google Search Method

| GSM | | | |
|---|---|---|---|
| | 10/05/01 | 12/31/01 | Change |
| 802.11a | | | |
| 802.11b | | | |
| Bluetooth | | | |
| 3G AND Wireless | | | |
| Hiperlan | | | |

Hz

LAN

5GHz

802.11a

UWB

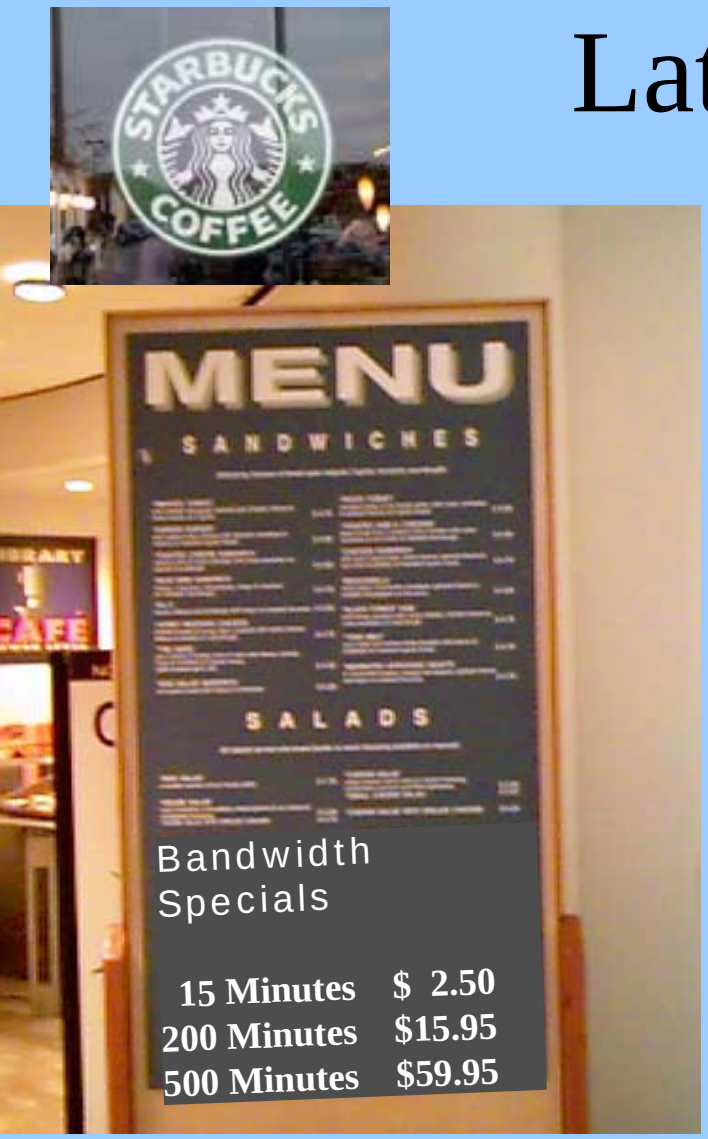
2.4GHz

802.11b

ooth

.

# Latte & 11Mbps




- "90% of Customers Heavy WWW Users"
- 2100 North America Stores Within 2 Years
- Increase Off-Peak Traffic
- High BW Haven For Road Warriors

*"oh no, if Starbucks starts offering 802.11 Service, I may never go home again" - recent posting*

# Latte & 11Mbps

- "99% of Customers Heavy WWW Users"
- 2100 North America Stores Within 2 Years
- Increase Off-Peak Traffic
- High BW Haven For Road Warriors

**August '01 - Cerulic wireless service provider, closes after 16 months of operation**

**October 10 '01 - Mobilestar closes after 5 years of operation & $53M+ In Funding**

**October 26 '01 "Rumors of Demise Premature"**

**Boingo Wireless - Secures $15M Funding**

**Sky Daton Founder of Earthlink**


*"oh no, if Starbucks starts offering 802.11 Service, I may never go home again" - recent posting*

# 802.11- The Napster of Bandwidth ?

## San Francisco Bay 802.11b Wireless Internet Access Point List

Maintained by cliff@steam.com for BAWUG

| Sponsor | Address | City | Zip | Network | Type | Info | ID |
|---|---|---|---|---|---|---|---|
| Sean Berry | Live Oak Ave btw El Camino and Curtis | Menlo Park, CA | 94025 | ESS: hbsdwn | Open, NAT | map url email | 15 |
| Dana Street Roasting Co., Live.com | Dana and Blossom | Mountain View, CA | 94041 | IBSS: LIVE.COM | Open | map url email | 2 |
| Hussein Kanji | Villa and Higdon | Mountain View, CA | 94041 | ESS: coulera-1 | Open, NAT | map email | 8 |
| Aaron Voisine | 680 Bellflower Ave. | Sunnyvale, CA | 94086 | ESS | open, NAT | email | 13 |
| Alex Chaffee | 15th and Ramona | San Francisco, CA | 94103 | ESS: Ramona | Limited, NAT | map email | 7 |
| Cory Doctorow | Portrero and 24th | San Francisco, CA | 94107 | ESS | Open, NAT | email | 19 |
| Cory Doctorow | Folson near 7th | San Francisco, CA | 94107 | | | | |
| Matt Peterson | 1st and Folsom | San Francisco, CA | 94107 | | | | |
| Jason Luther | 17th and Diamond | San Francisco, CA | 94114 | | | | |
| Christian Wolff | Chattanooga btw 23rd and 24th | San Francisco, CA | 94114 | | | | |
| Robert McIntyre | California and Divisidaro | San Francisco, CA | 94115 | | | | |
| Butterzone SF | Quintara and 26th Ave. | San Francisco, | 94116 | | | | |
| Tim Pozar | 1978 45th Avenue | San Francisco, CA | 94116-10 | | | | |
| feddle.net | Cole and Waller | San Francisco, CA | 94117 | | | | |
| Kevin Burton | 1300 block 8th Ave | San Francisco, CA | 94122 | | | | |
| Tristan Horn | 65 Borica St. | San Francisco, CA | 94127 | | | | |
| Toaster Networks | Duncan btw. Church and Sanchez | San Francisco, CA | 94131 | | | | |
| Swan's Market, Old Oakland | Clay btw. 9th and 10th | Oakland, CA | 94607 | | | | |
| Cody Oliver | Stuart Street, 1800 block | Berkeley, CA | 94703 | | | | |
| Frederick Shoul | 466 Madison Street | Santa Clara, CA | 95050 | | | | |

AP HOT SPOTS

Edit View Actions Tools Window Help

"Wayport" <wayport_xp@norm.nmailer.com>

CC:

"" <vollkomm@symbol.com>

ect: Wayport Thanks You

sage:

Close

Reply

Forward

Delete

# Wayport's e-Newsletter:

*Keeping you up to speed.*

WAYPORT. Fast Net for People on the Move

## Welcome

Dear Windows XP customer:

The Wayport team would like to thank you for using our service during the **Ride Wireless for Free with Windows XP** promotion. We hope you enjoyed our high-speed Wi-Fi wireless Internet access in over 450 hotel and airport locations.

We invite you to take advantage of our **Membership programs**, which provide **unlimited Wi-Fi (802.11b) wireless* and wired connectivity** in any Wayport-enabled hotel or airport, plus your first five minutes of workstation time **free** in our Laptop Lane airport business centers.** All for one low monthly rate!

**Individual Membership:** Unlimited connectivity for just **$29.95** per month. Based on a yearly agreement.
**Corporate Membership: Special rates** on unlimited connectivity for organizations with 50 or more members. Comes with powerful online administrative tools for quick and easy account management.
**Month-to-Month plan:** One month of unlimited access with no yearly commitment for just **$49.95.**

Sign up today or CLICK HERE for more information.

Additionally, you may purchase single, twenty-four hour connections at any Wayport location. (See http://www.wayport.net/locations for a complete list.)

2/8/02 11:24AM

# 802.11 Hotspot Market

- Deployment Growth

| | Number of public sites | | | |
|---|---|---|---|---|
| | Domestic | | International | |
| Site Type | **2001** | **2002** | **2001** | **2002** |
| **Airports** | 8 | 25 | 4 | 10 |
| **Airline Lounges** | 40 | 100 | 40 | 80 |
| **Hotels** | 400 | 900 | 200 | 500 |
| **Retail** | 900 | 4000 | NA | 1000 |
| ***Total*** | ***1348*** | ***5025*** | ***244*** | ***1590*** |

Greg Homan - MobileStar Networks

- Subscriber Market Growth In North America
  (Joshua Wise, senior analyst at Allied Business Intelligence)
  - $1.1M in 2000
  - $868M in 2006

# Is 802.11 A Technology Disruptor For 3G?

"Disruptive Technologies", Joseph Bower, Clayton Christensen

- Non Disrupter Technologies
  - Follows known (or perceived) customer needs
  - Market seems assured
  - Innovation Twists On Existing Paradigms
  - "We need a wide are technology with high speed data capability"
- Disruptors:
  - "do not meet current customers' needs" (wide area access)
  - "look financially unattractive to established companies"
  - "difficult to project how big the market will be over the long term"
  - "typically present a different package of performance attributes"
  - Often Performs Worse In Dimensions Important To Mainstream Customers

# Disrupter Rumblings

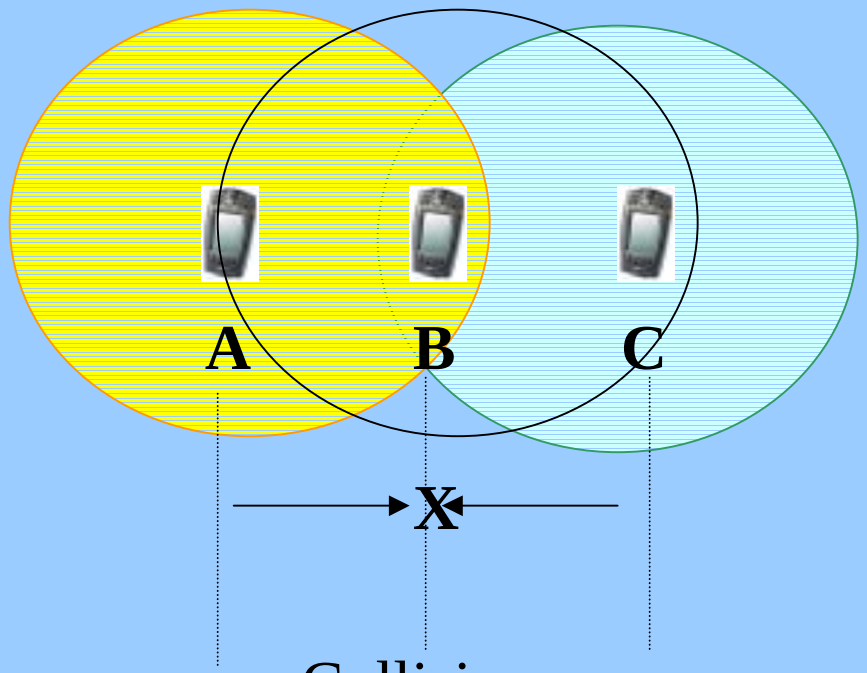
- “For 3G operators, 802.11b threatens to render obsolete the business model they bet on at last summer's European spectrum auction. That is because it is a "bottom-up" technology being rolled out by firms with no plans to make money from it, according to Rohit Sobti, head of Asia-Pacific telecommunications research at Salomon Smith Barney.”

- When Will It Be A Definitive Disrupter?
  - Large Following of Residential & Corporate
  - Critical-Mass Availability (Airports, Hotels…)
  - Roaming/Billing Agreements Among Service Providers

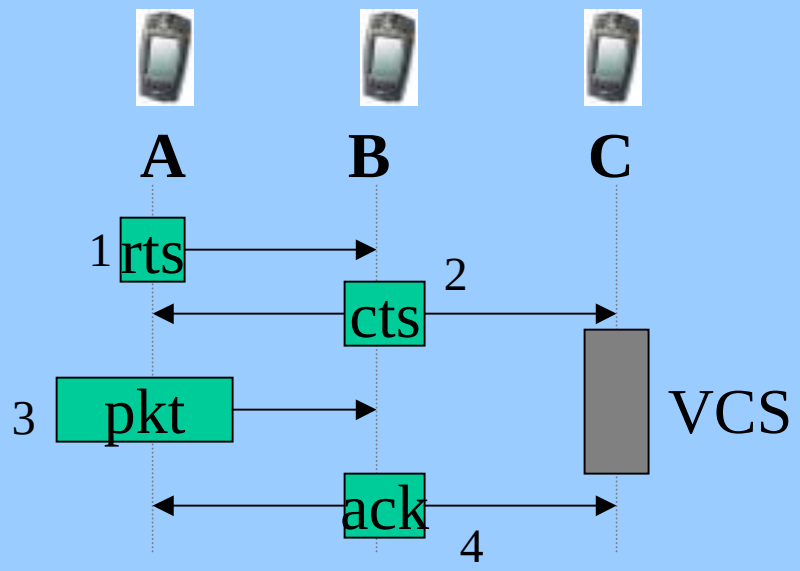
# Good Technical Forethought

- Common MAC Multiple PHY's
- BSS (wire connect) & IBSS (Adhoc network)
- Extended Service Set (ESS) Roaming
- CSMA/CA Instead of CSMA/CD
- Hidden Terminal Resolution
- Point Coordination For Contention Free
- Country Roaming
- Wired Equivalent Privacy (WEP)

# Hidden Terminal "Resolution"



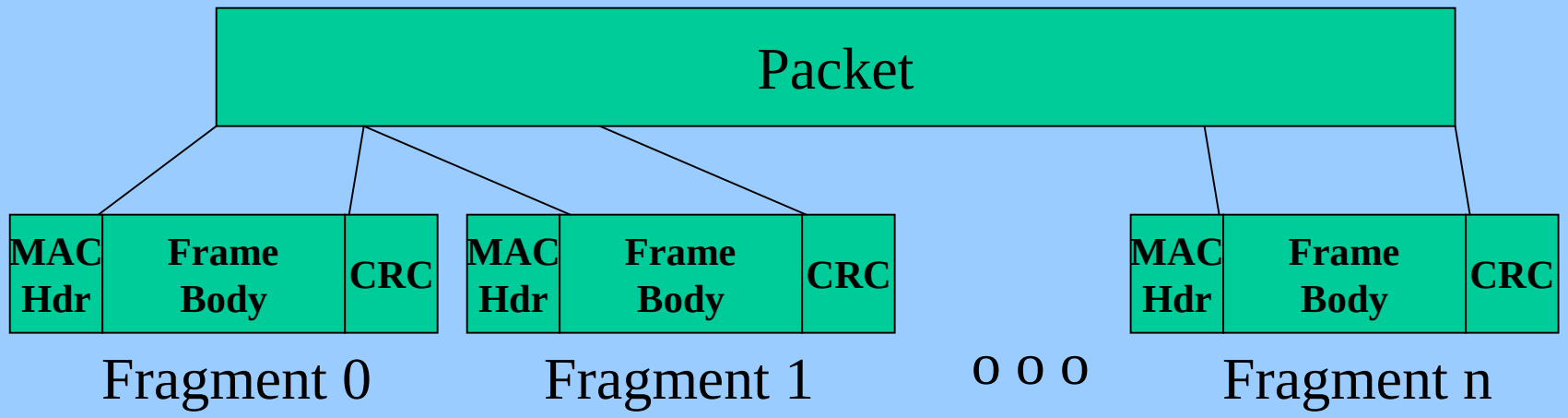

Collision
@ B




4Pkt vs 2Pkt Controllable Through dot11RTSThreshold

The Good

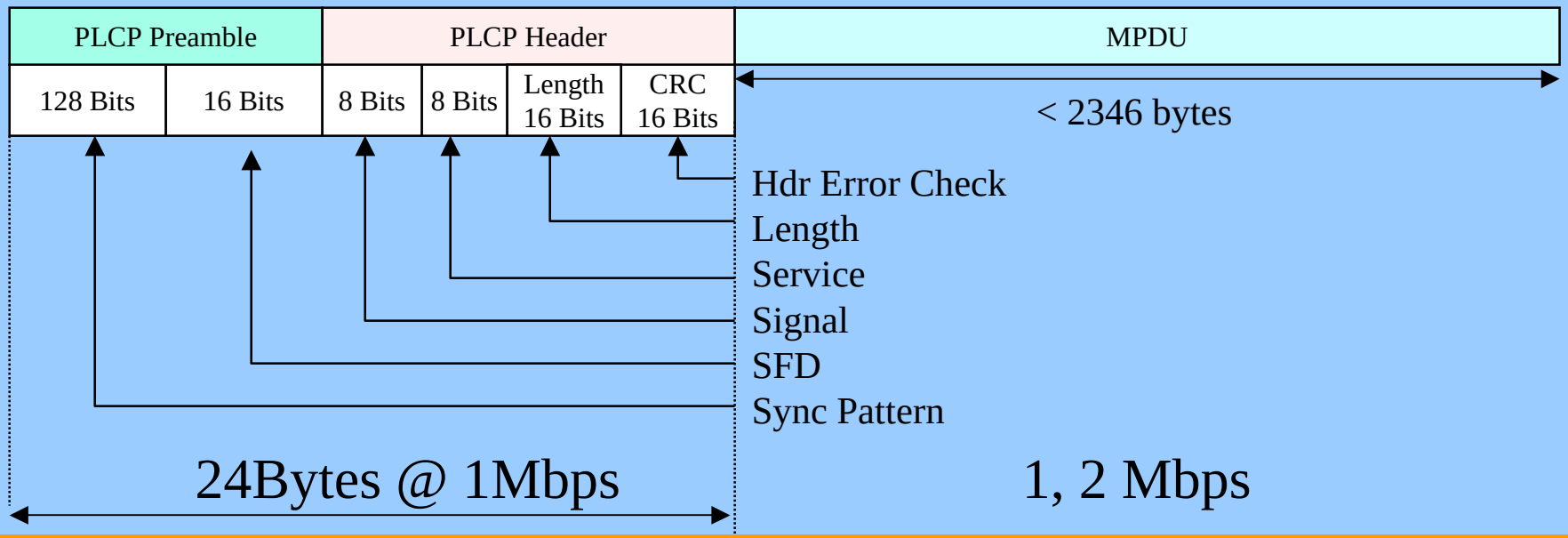
# Link Layer Fragmentation & Reassembly




- Fragmentation/Re-assembly Not Typical For Link Layer
- Link Acks but no windowing
- Increase P(success) - Message vs Pkt Switching
  - **2048 byte @ $10^{-4}$ BER = 1.942747E-01**
  - **64 byte @ $10^{-4}$ BER = 9.500862E-01**

~3x Net First Order Improvement For 2048Bytes

# Multi-Data Rate Frame Structure For DS




802.11b

Long (interoperable)

1Mbps

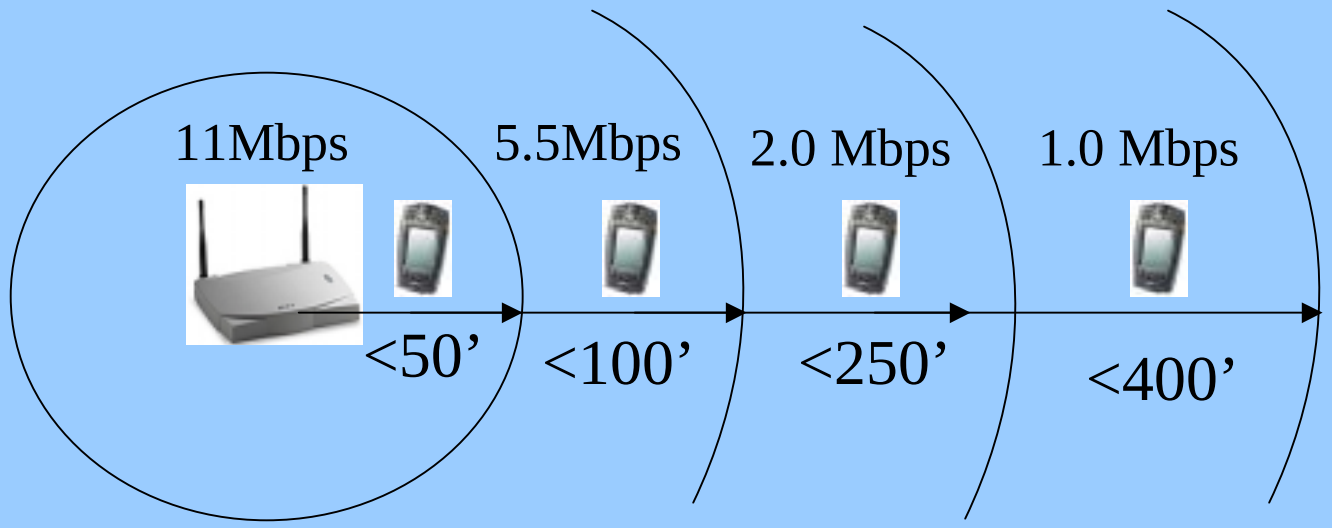
1,2, 5.5, 11 Mbps

1M PLCP Preamble - 2M PLCP Hdr

Short

2, 5.5, 11 Mbps

# Good News- Adaptive Data Rates

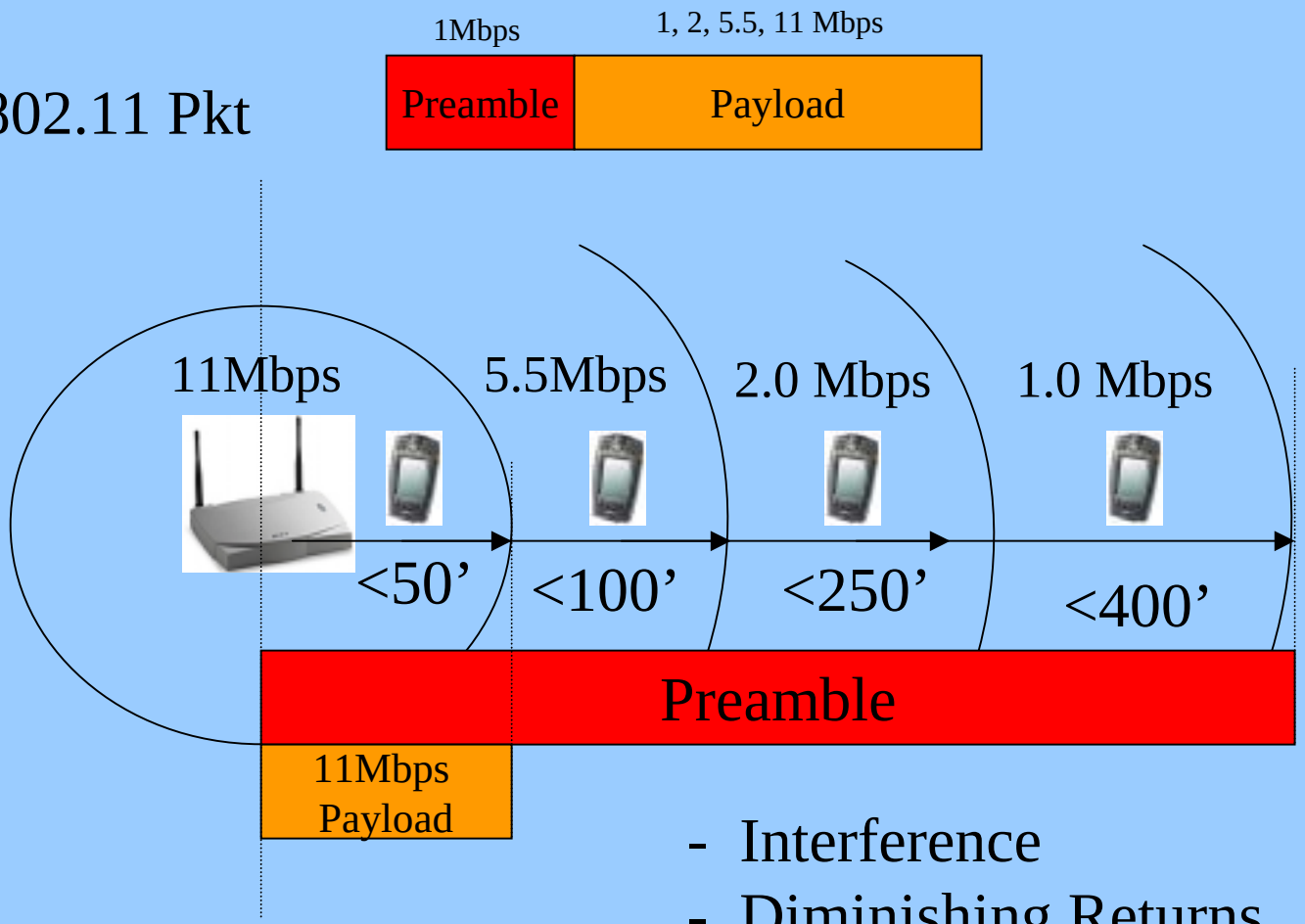



Distances Are Typical for indoor applications
with 100mW transmitter
(early generation receivers– Good News For Later Receivers)

The Bad

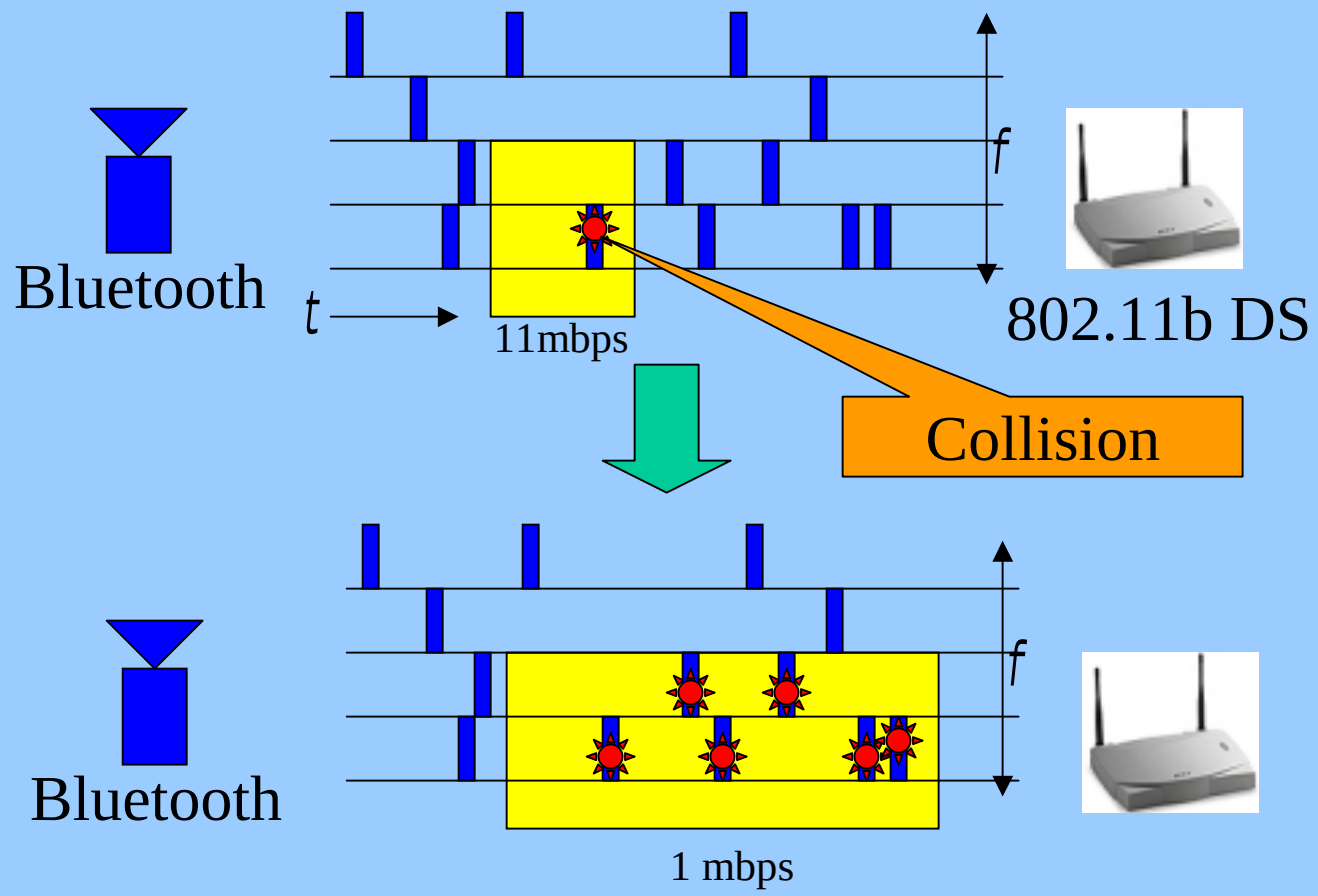
# 1Mbps Preambles Always

802.11 Pkt




- Interference
- Diminishing Returns of Higher Data Rates

# Rate Change Countermeasure Not Always Obvious In Mixed Environments



The Bad

# WLAN (In)Security

## *WEP Vulnerabilities*

The New York Times

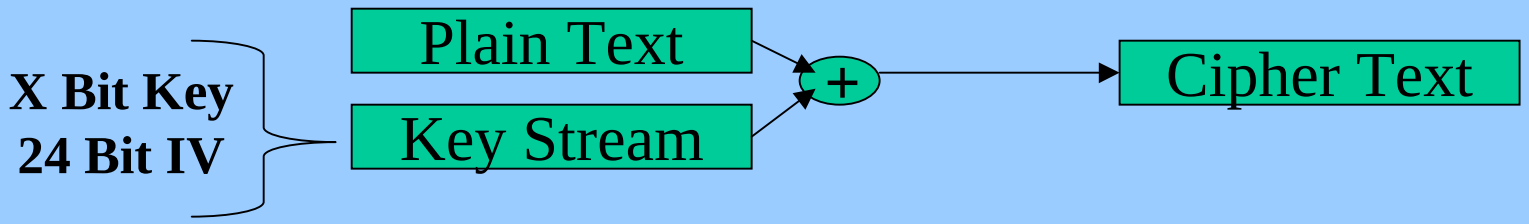
**April 3, 2001 "Flaw in Popular Wireless Standard"**
**By JOHN MARKOFF**

- Flawed Authentication
- Flawed IV usage
  - Too small (24 bit)
  - No IV collision avoidance
  - Some reset IV to 0 upon start
  - per pkt key = IV || secret key
- RC4: Not checking weak keys
- Flawed integrity check: use linear CRC-32
- Stateless (no seq. no.)
- Same key AP→MU→AP
- No key distribution or dynamic keying mechanism

- Authentication spoofing
- Decryption dictionaries
- XOR of two plaintexts
- Message injection
- Recovery of secret keys
- Message modification
- Inductive chosen plaintext
- IP redirection
- Replay Packets

Other attacks:
- Double encryption,
- Reaction attacks,
- Password cracker, DoS…

# IV Paradoxes w/Stream Cipher



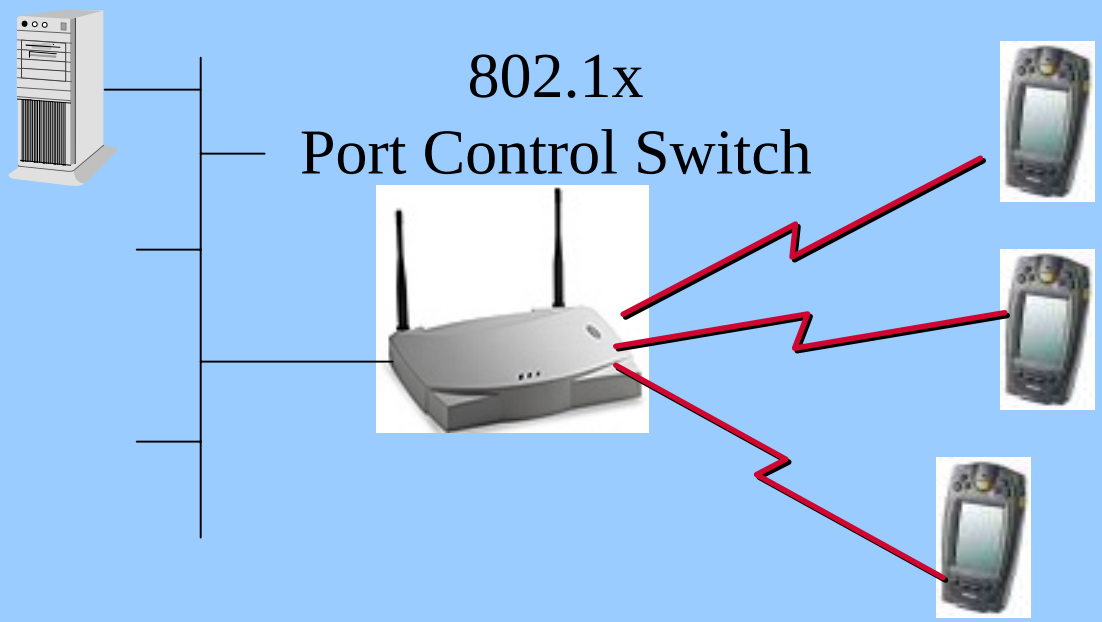

*Repeated Key Streams Vulnerable To Known Plaint Text Attack*

- Key Is Constant → Only IV Makes A Difference
- Key Is Shared → Large # of Users
- Unreliable Link Resynch Every Pkt → IV Changes Every Pkt
- No IV Select Protocol → IV Re-Use

***Bottom Line Key Stream Repeats Easily In < 1Hour***

# 802.11i Security Work-In-Progress

Operable with;
Radius, Kerberos…

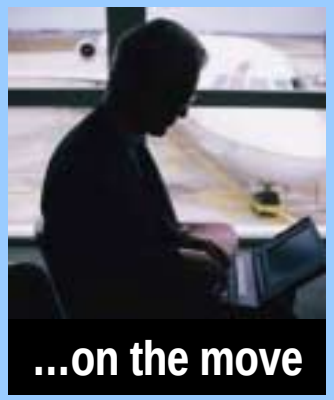



- Per-Session Keys
- Mutual Authentication
- AES
- Larger (>24bit) IV
- Fast Roaming
- Secure Hash ICV
- EAPOL/802.1x

The Good

# Making 802.11 Easier To Use






X = ESSID

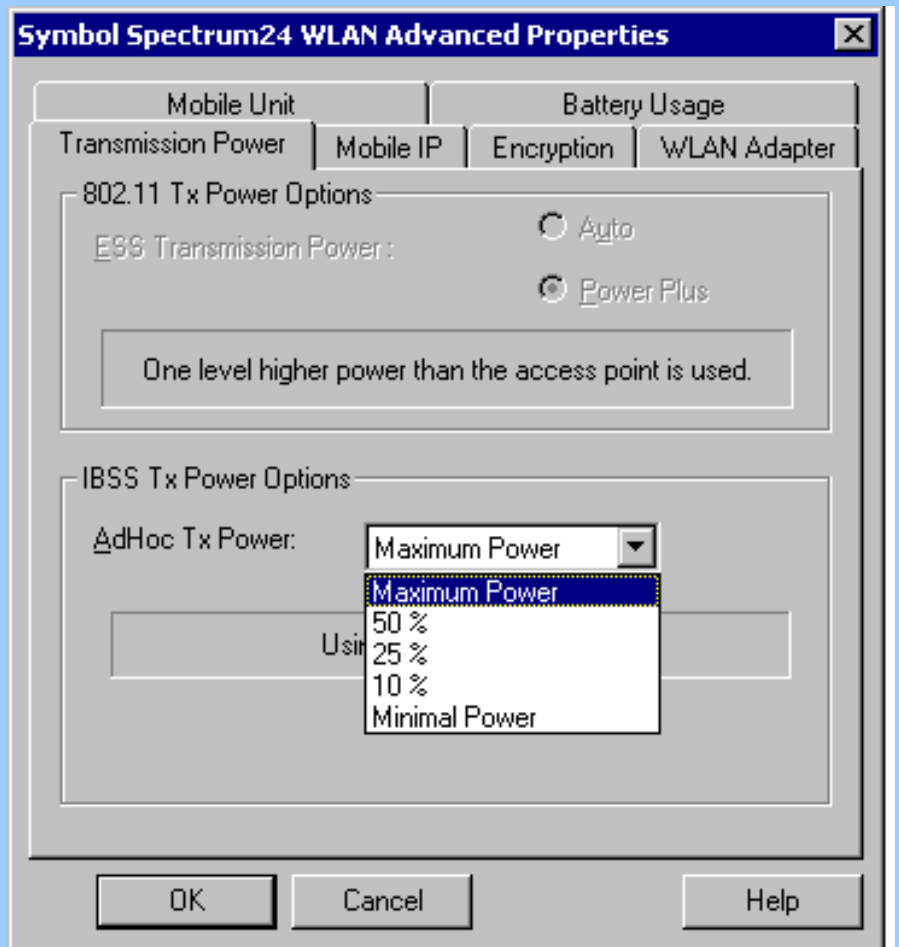
?

?

?

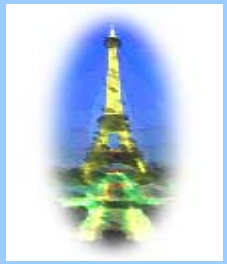
The Good

# Improving Capacity & Battery Life
# Transmit Power Control



# Improving Interoperability

# Operation in Additional Regulatory Domains (802.11d)



France

Netherlands

USA

- Listen first
- Find out the country
- Transmit

# Smaller Form Factors

The Good

Type 2 PC Card


**–110mm (4.3”) x 54mm (2.1”)**
**(including antenna)**

Symbol
Type I CompactFlash


~3.7 sq”

**–55 mm (2.2”) x 43 mm (1.7")**
**(including antenna)**

## 60 % Reduction In Total Size

The Ugly

The New York Times

# ISM Band

**“Protocol Wars: A Standard Emerges, but Watch Out for Those Microwave Ovens”**

By GLENN FLEISHMAN February 22, 2001

Baby Monitors

802.11 2.4GHz
Industrial, Scientific, Medical

Commercial & Residential Microwaves

“We Live In An Interference Limited World”
Prof Dave Goodman Polytech Univ

ISM – 902-928MHz

ISM – 2400-2483.5MHz

Panasonic

46-49MHz
900MHz

390 Mhz

AMPS cellular
820-890MHz

Airfone Commercial (air-ground) 850-895MHz

Cordless Phones
902-928MHz


2.4G Video Distribution

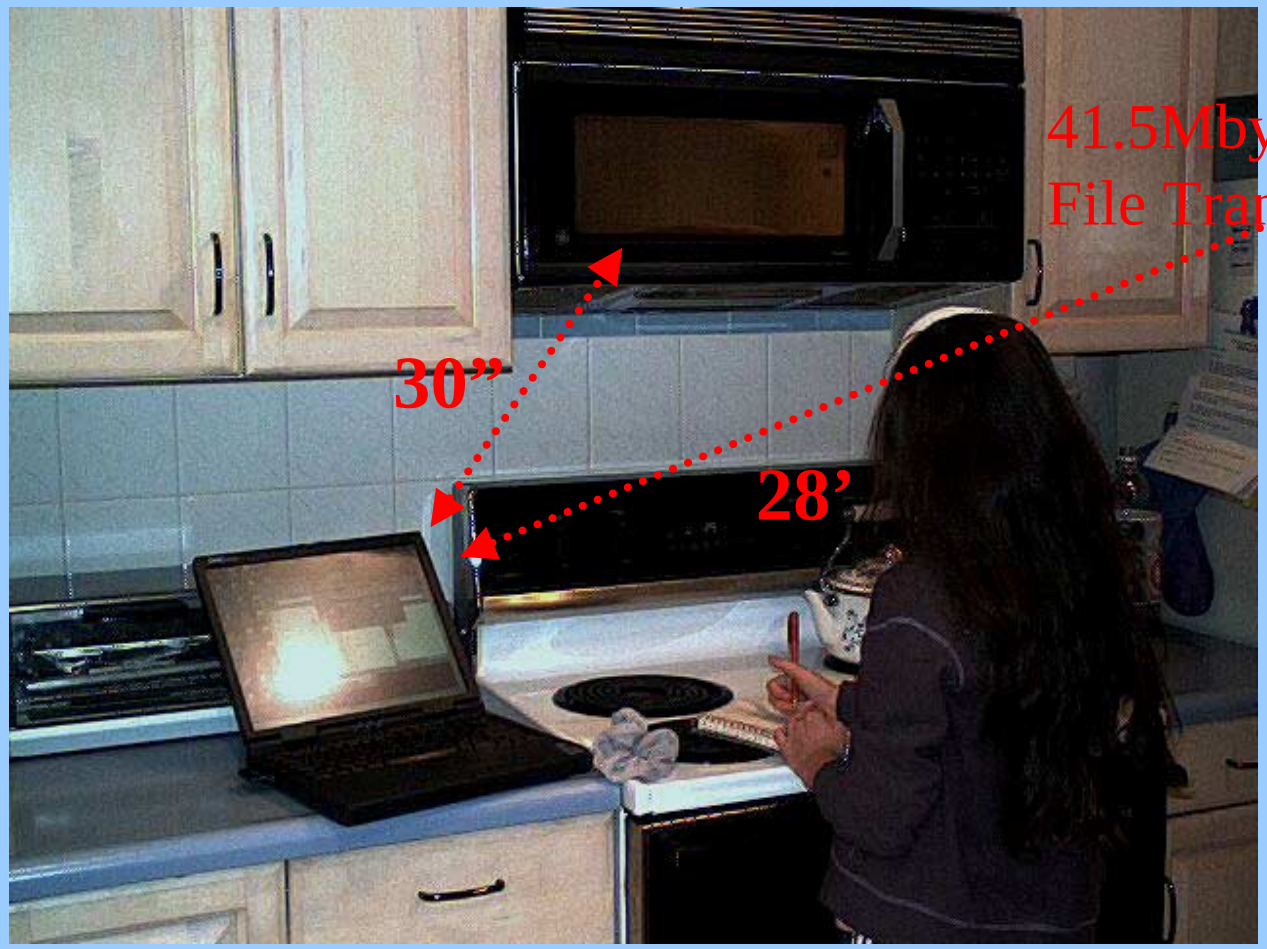
2.4G Headsets

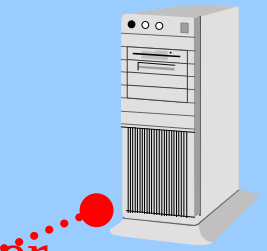
Cordless 25 Channel
43.7MHz-49.97MHz

HomeRF

Bluetooth

# Empirical Microwave Impact



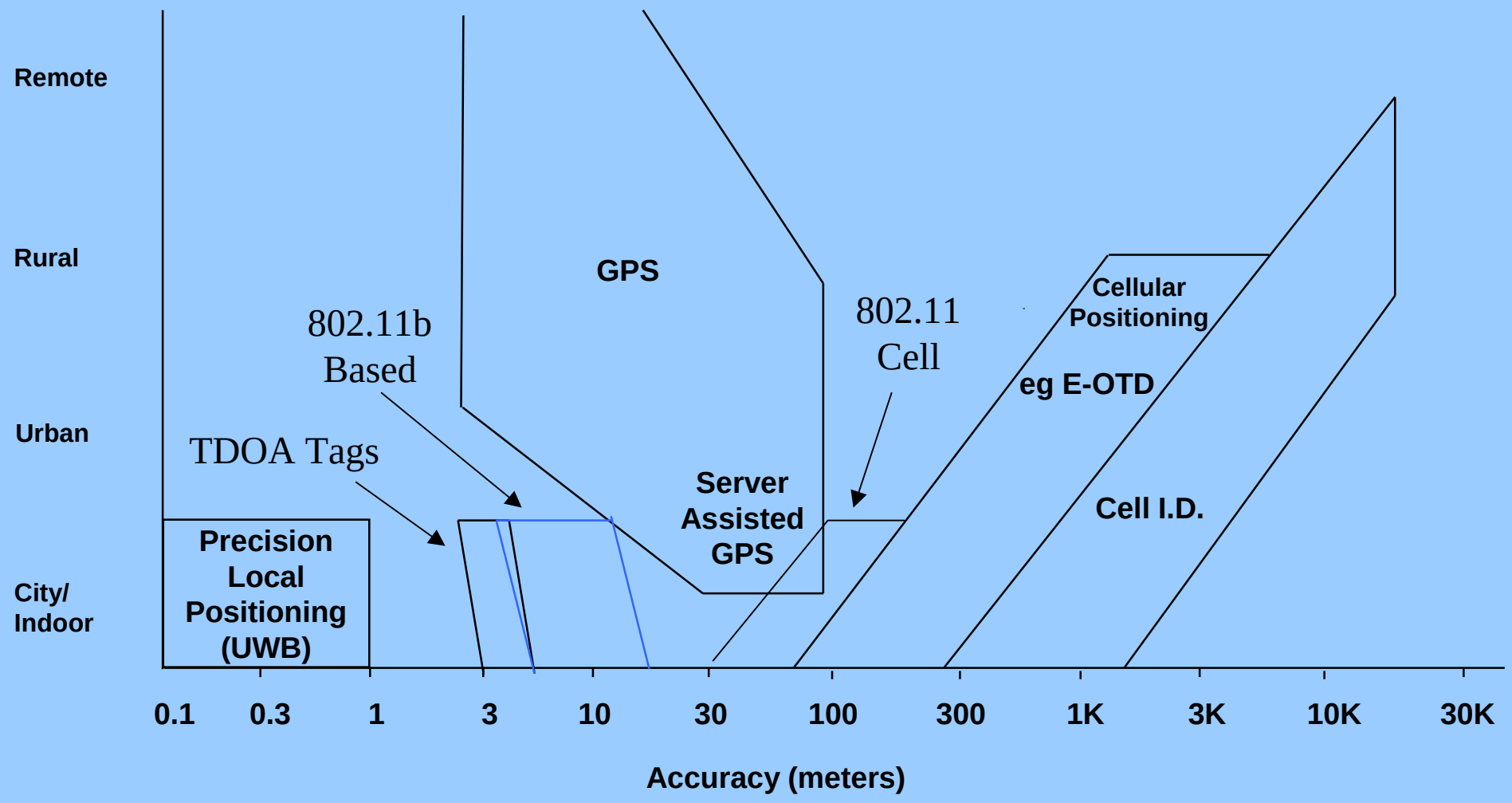
41.5Mbyte
File Transfer

Microwave Off = 80 seconds
Microwave On = 81 seconds

(avg throughput = 4.15Mbps)

The Good

# 802.11 Advanced Services - Positioning



# Seamless Horizontal & Vertical Roaming

| | | | |
|---|---|---|---|
| WWAN | GSM/GPRS Base Station 1 | GSM/GPRS Base Station 2 | GSM/GPRS Base Station 3 |
| WLAN | Access Point AP 1 | Access Point AP 2 | Access Point AP 3 |
| WPAN | Bluetooth Master-1 | Bluetooth Master-2 | Bluetooth Master-3 |

Horizontal Roaming

Vertical Roaming

# The Road Ahead For WLAN

Soft & Multi-Waveform Radios

Opportunity Aware Radios (info-stations)

Zero Configuration e.g. AP Proxies

CDAC (channel detection & correction) - DFS

"Adaptive"; Power (TPC), Data Rates/FEC

Space & SDMA

Seamless Horizontal & Vertical Roaming

Middleware: Air Interface & Platform Agnosticism

---

Wireless Intelligence Si vs (Physics & FCC)

More Wireless Service Providers

Enhanced CoS & QoS 802.11i

High Bandwidth >54Mbps 802.11a

More Security 802.11e

# Bluetooth

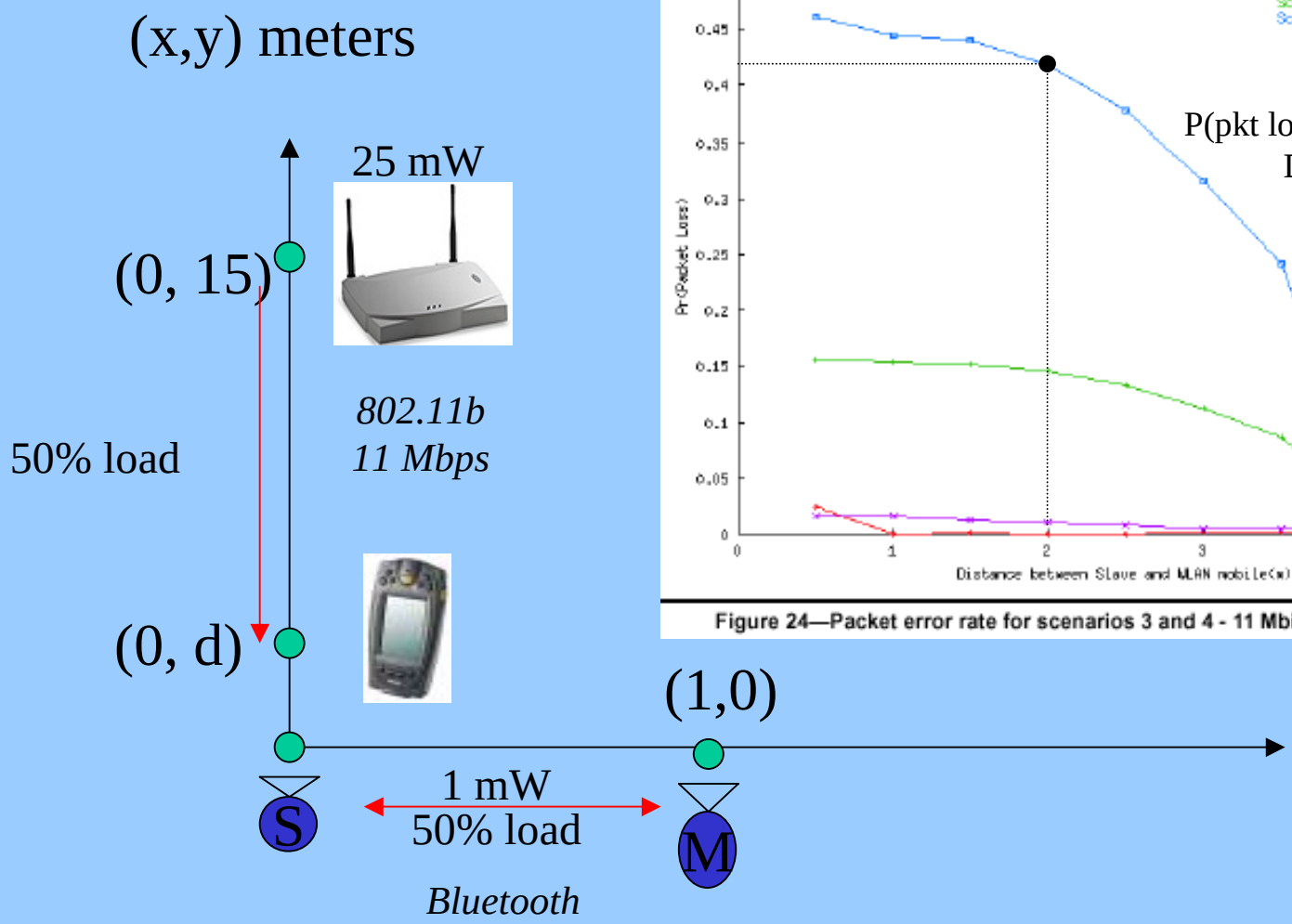
- Why Bluetooth?…….Power, Cost, Isoch?
  - FH vs DS
  - Sensitivity
- "The only real advantage is power consumption. [illegible] is important to you, just turn the power down on the 802.11b radio," -- Craig Mathias, principal at the Farpoint Group
- "In other words, a low power, short range 802.11 could beat it." David Reed

**Its All A Matter Of Standby Power**

| | Power (Watts) | | uWatts / Bit | |
|---|---|---|---|---|
| | Bluetooth | 802.11b | Bluetooth | 802.11b |
| Rx | 0.204 | 0.540 | 0.31 | 0.09 |
| Tx | 0.186 | 1.230 | 0.29 | 0.21 |
| Standby | 0.0001 | 0.048 | 0.0001 | 0.0480 |

# Bluetooth-802.11b

Temporal or Adaptive FH (recently approved by FCC for Bluetooth)



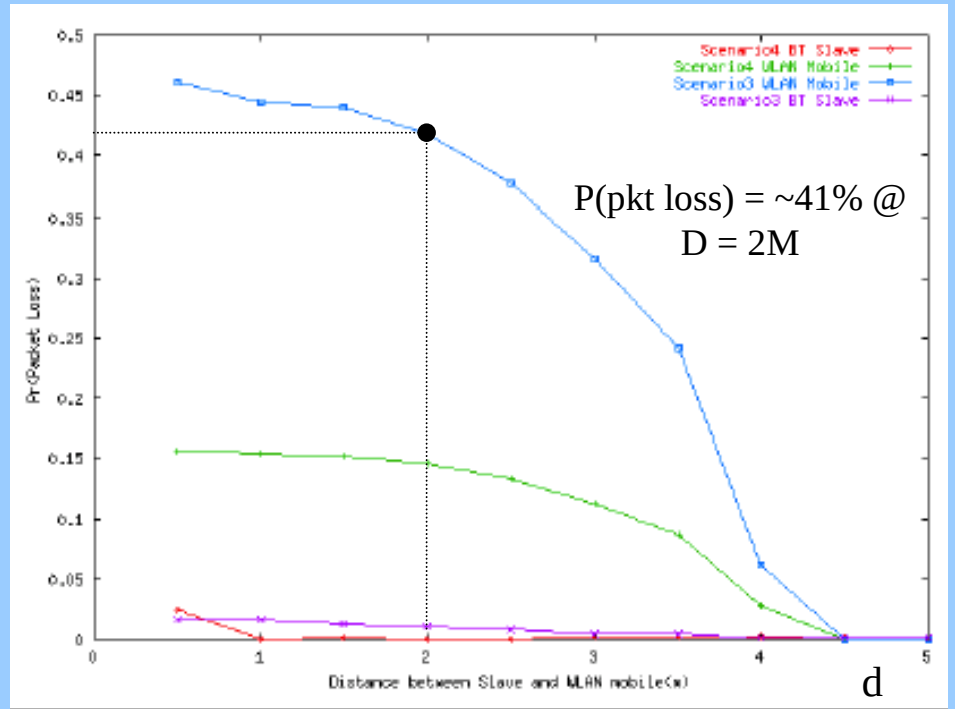




Figure 24—Packet error rate for scenarios 3 and 4 - 11 Mbit/s direct sequence

* Draft P802.15.2/D02-2002

# Killer Bluetooth App?

*My Kids Say Yes !*

# Why 3G?

## aka. 21st Century Public Works Program For Engineers




# What Were The Other G's?

- **Simple version:**
  - 1G=analog
  - 2G=digital (GSM, PDC, CDMA, TDMA)
- **More detailed version:**
  - 2G = more capacity per RF channel
  - 2G = more battery life
  - 2G = more features/services
  - 2G = no static (-- no voice)
  - 2G = low rate data
- **And ½ G's: 2.5G (e.g. GPRS: 32+Kbps)**

The Good

# 3G

- Higher Data Rates:
  144+Kbps, 384Kbps….2+Mbps
- Licensed Spectrum (not ISM or U-NII)
- Universal Roaming
- Packet Switched / “Always-On”
- “Enabler For Killer Applications !!”

The Bad

# "What Killer Applications?"

Voice?

Streaming Video?

HS Web Browsing?

?….uh

**"We Don't Need No Stinkin' 3G Data Rates"**

Steve Milunovich, Merrill Lynch & Co.

(data rates for video – but who watches video on a cell phone?)

## ***Heresy or Insightful Prophecy?***

- **"There is no reason anyone would want a computer in their home."** --Ken Olson, president of Digital Equipment Corp., 1977
- **"640k should be enough for anybody"** - Bill Gates
- **"Who Wants to Hear Actors Talk?"** - H.M. Warner, Warner Brothers, 1927

# Questions?

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