UWB (WPAN)

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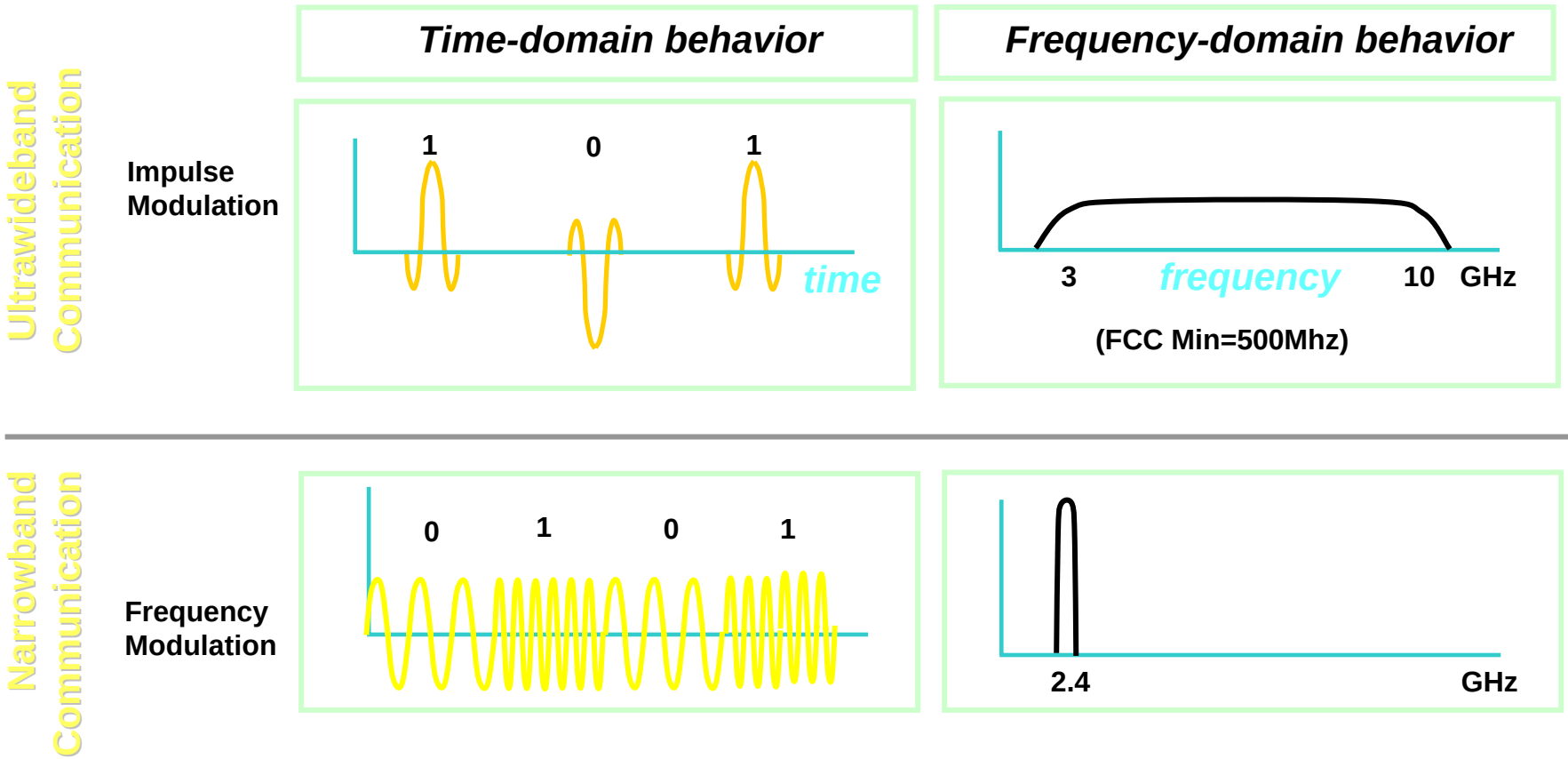
Outline

- UWB basics
- UWB for WPAN

UWB basics

What is UWB?

UWB is a radio technology that modulates impulse based waveforms instead of continuous carrier waves



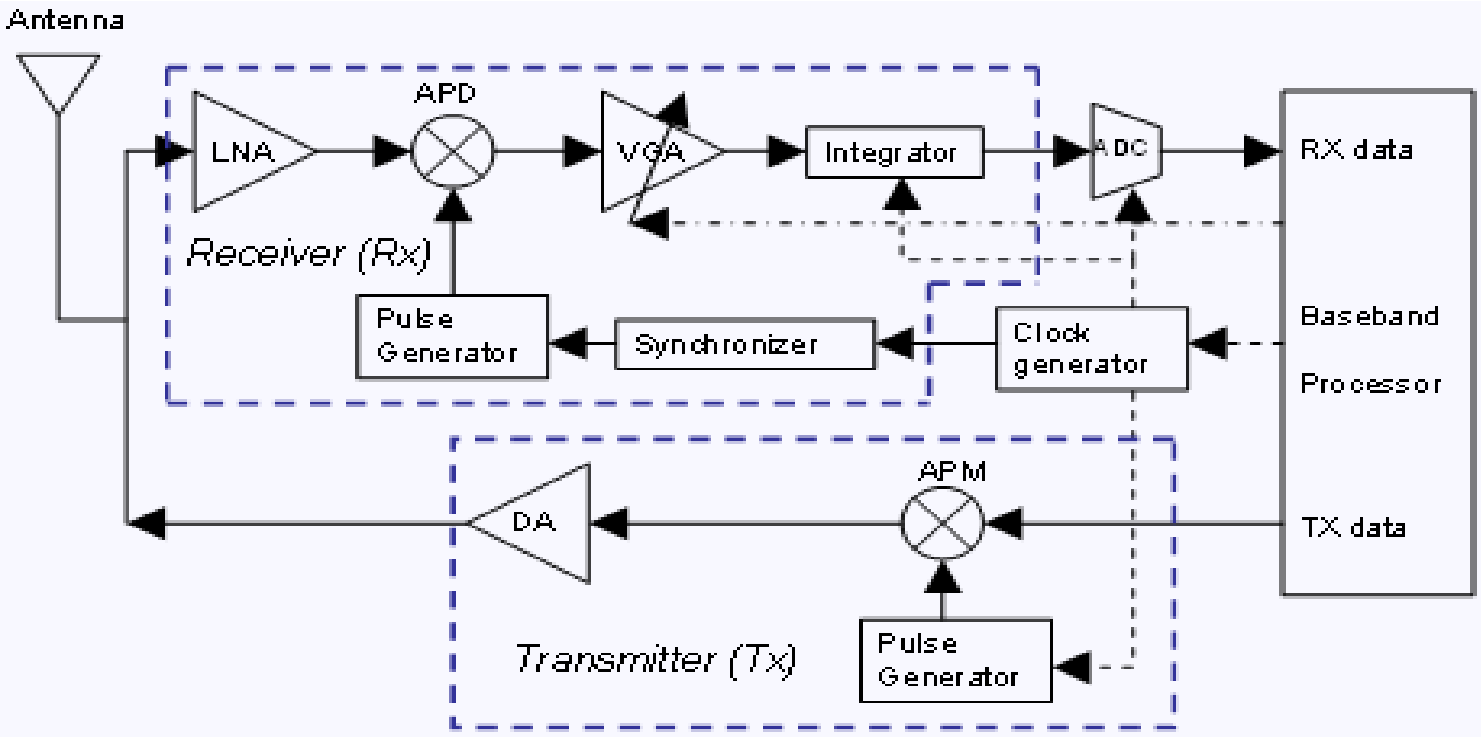
Channel model

The UWB channel can be described by its time-variant impulse response $h(t,\tau)$, which can be expressed as

$$h(t,\tau)=\sum_{n=1}^{N(t)} a_n(t)\delta(t-\tau_n(t))e^{j\theta_n(t)} \qquad (1)$$

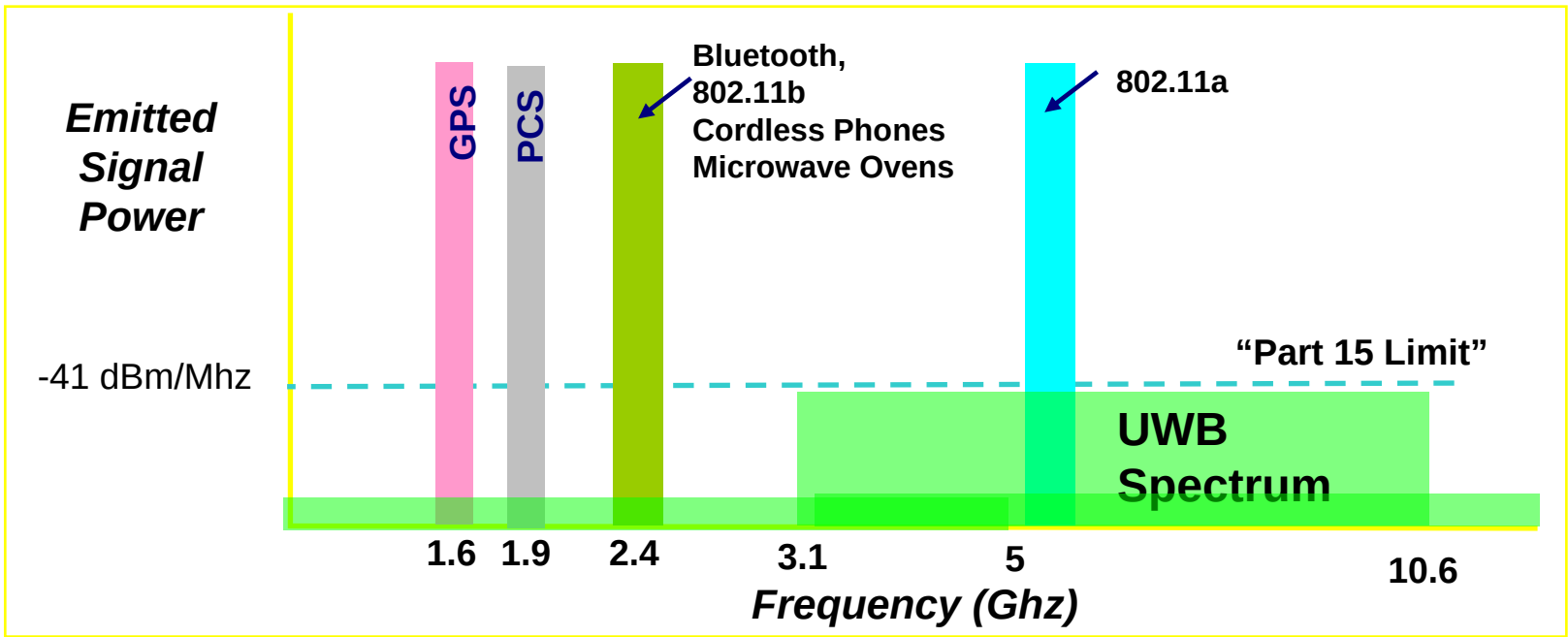
where the parameters of the nth path a_n, τ_n, θ_n, and N are amplitude, delay, phase, and number of relevant multipath components, respectively.

UWB Transceiver System Diagram [12].



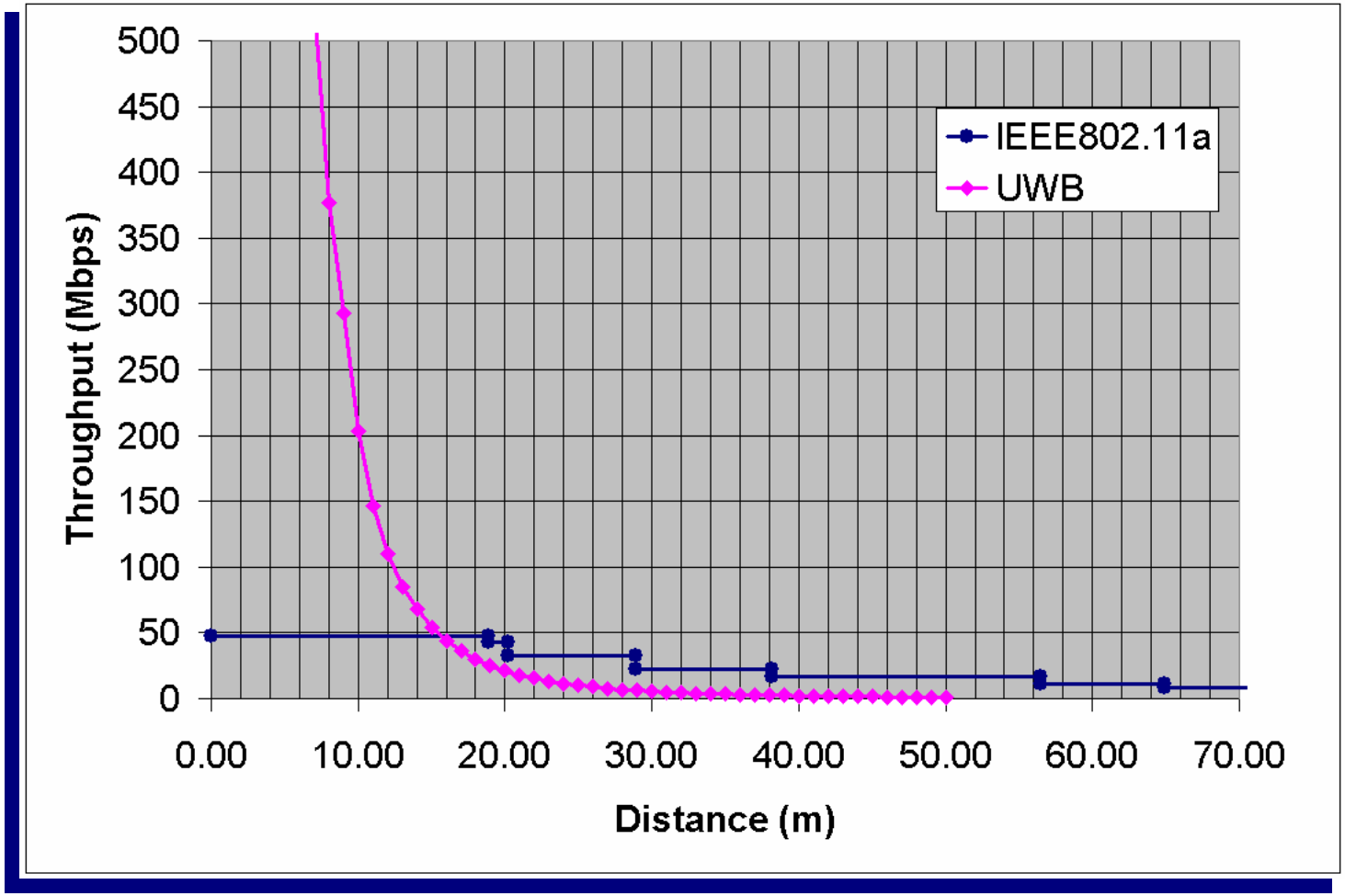
UWB Spectrum

- FCC ruling permits UWB spectrum overlay



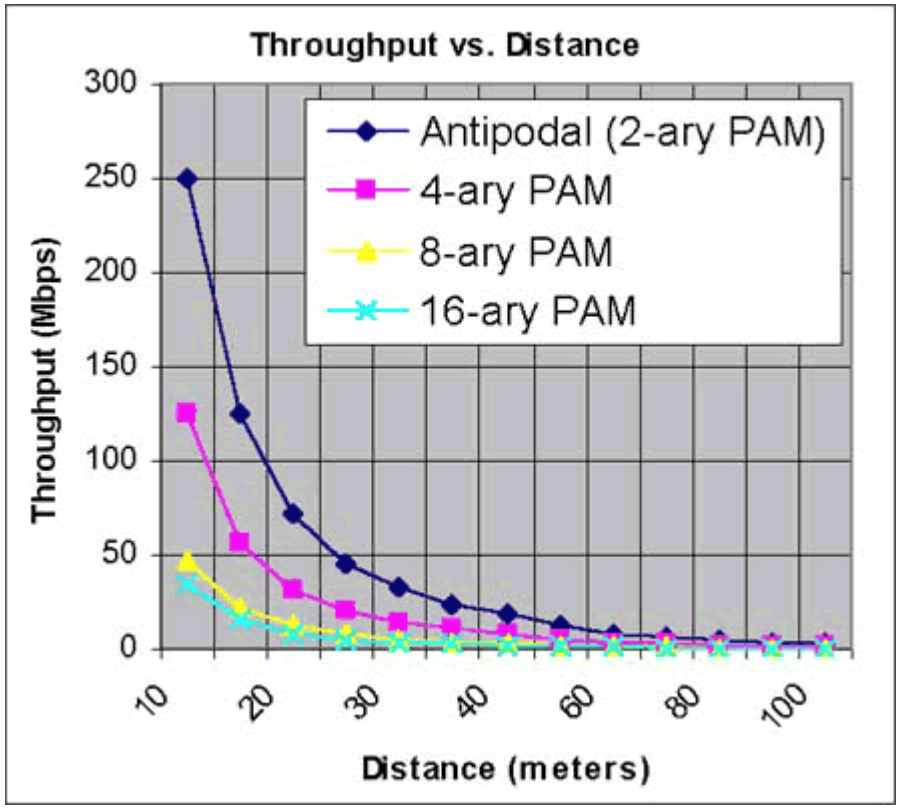
- FCC ruling issued 2/14/2002 after ~4 years of study & public debate
- FCC believes current ruling is conservative

Theoretical Data Rates over Range



UWB shows significant throughput potential at short range

Performance Analysis with encoding rules



EXAMPLE UWB LINK ANALYSIS

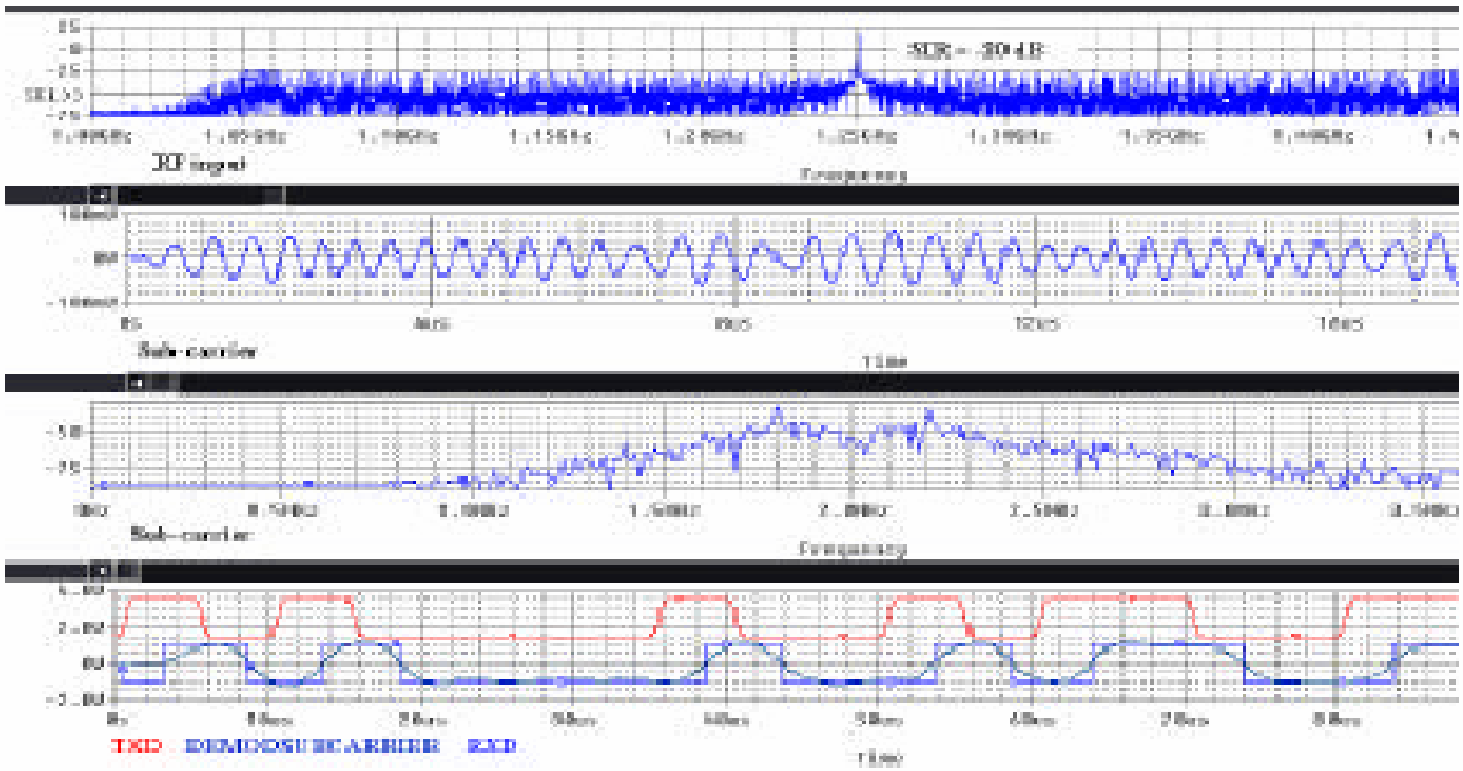
SIR = 20 dB!

Spectrum

Subcarrier (time)

Subcarrier (freq.)

Data



R = 200 kbps, Δf_{sub} = 2 MHz, Δf = 200 MHz, $\beta = \Delta f / \Delta f_{sub}$ =100 (20 dB)

So why is UWB so Interesting?

- 7.5 Ghz of “free spectrum” in the U.S.
  - FCC recently legalized UWB for commercial use
  - Spectrum allocation overlays existing users, but its allowed power level is very low to minimize interference
- Very high data rates possible
  - 500 Mbps can be achieved at distances of 10 feet under current regulations
- “Moore’s Law Radio”
  - Data rate scales with the shorter pulse widths made possible with ever faster CMOS circuits
- Simple CMOS transmitters at very low power
  - Suitable for battery-operated devices
  - Low power is CMOS friendly

Ultra Wideband Characteristics

- Extremely low transmission energy (less than 1mW)
- Very high bandwidth within short range (200Mbps within 10m)
- Extremely difficult to intercept
  – Short pulse excitation generates wideband spectra – low energy densities
  – Low energy density also minimizes interference to other services
- Multipath immunity
- Commonality of signal generation and processing architectures
- Radar
  – Inherent high precision – sub-centimeter ranging
  – Wideband excitation for detection of complex, low RCS targets

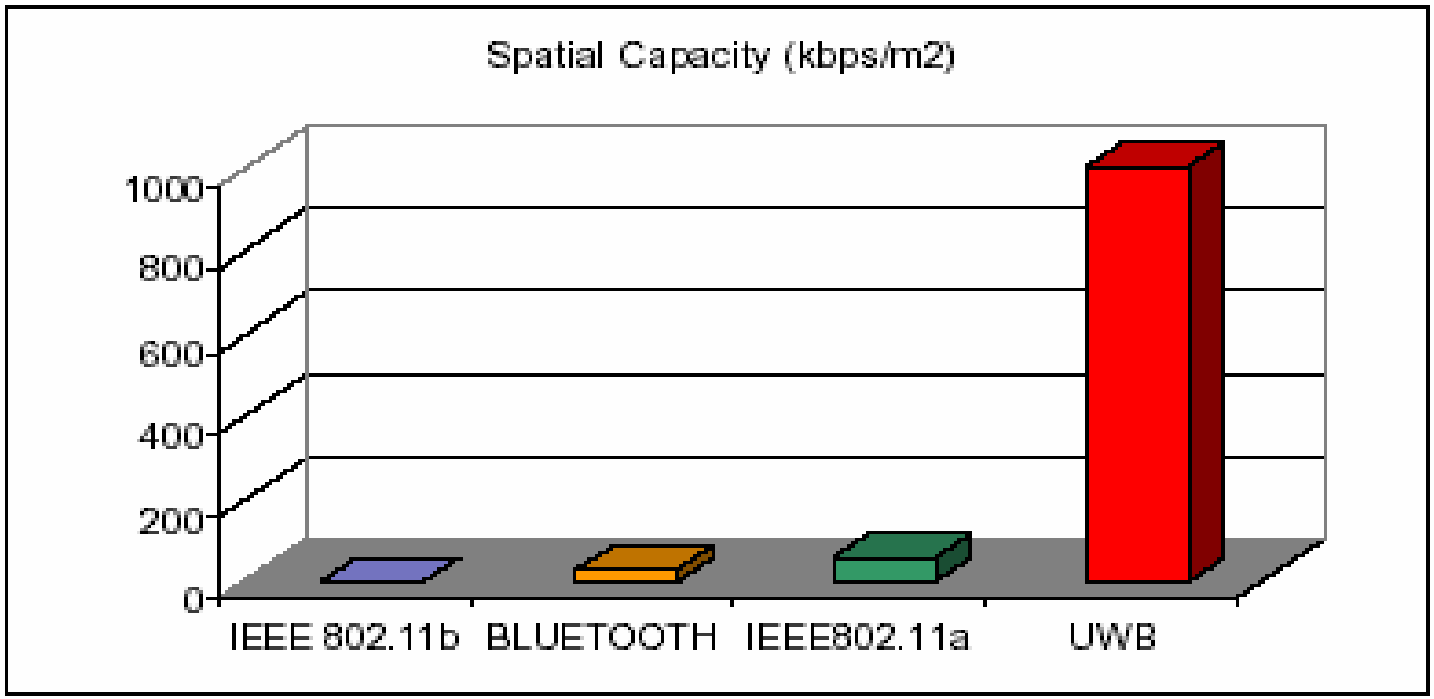
Ultra Wideband Characteristics

- Geolocation/Positioning
  - – Sub-centimeter resolution using pulse leading edge detection
  - – passes through building blocks, walls, etc. (LOS not required)
- Low Cost
  - – Nearly “all-digital” architecture
  - – ideal for microminiaturization into a chipset
- Frequency diversity with minimal hardware modifications

UWB Advantages

- Capacity
  - possibility of achieving high throughput
- Low power & Low cost
  - Can directly modulate a baseband pulse
  - Can be made nearly all digital
  - High capacity with lower Tx power levels
- Fading robustness
  - Wideband nature of the signal reduces time varying amplitude fluctuations (?)
  - Relatively immune to multipath cancellation effects
    - Path delay ~ 1ns > pulse duration
    - But don’t we build RAKE just to rebuild the multipath thing ?
    - What about ISI ?
- Position location capability
  - Developed first as radar technology (!)
- Flexibility
  - Can dynamically trade-off throughput for distance

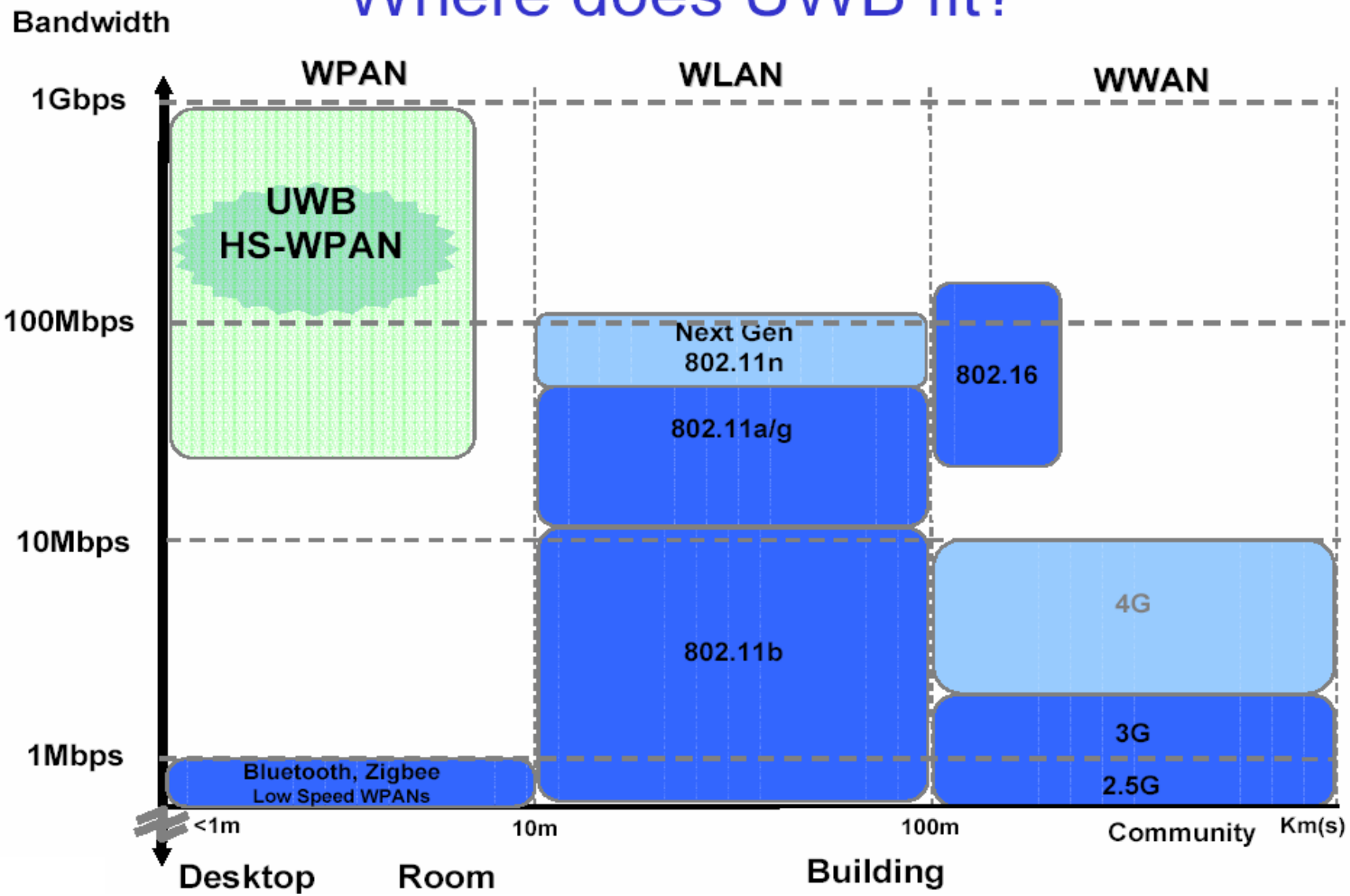
COMPARISON OF WIRELESS TECHNOLOGIES: CAPACITY

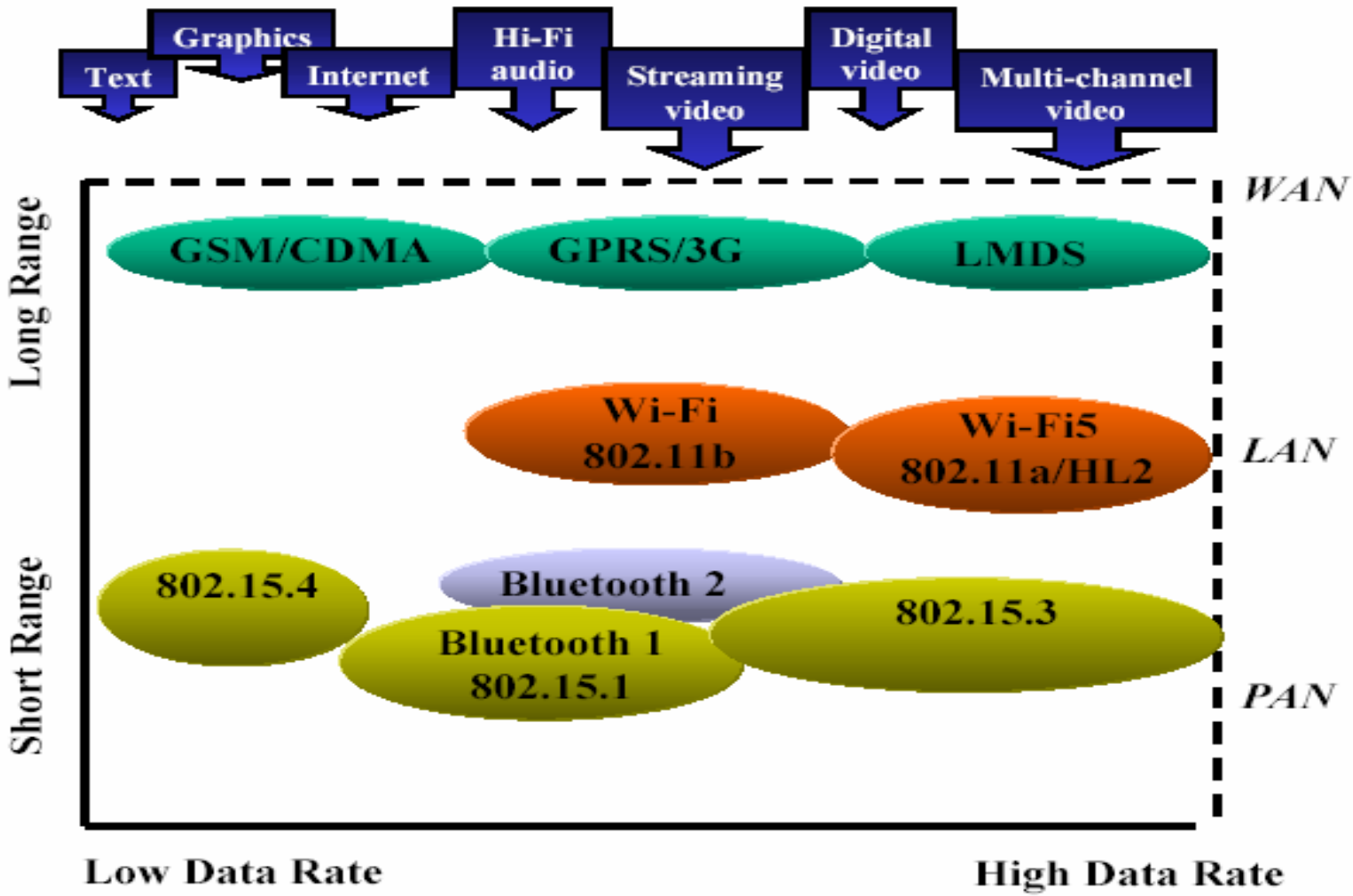


Sources: Scientific American, Time Domain, MSSI

UWB for WPAN

Where does UWB fit?




Text
Graphics
Internet
Hi-Fi audio
Streaming video
Digital video
Multi-channel video
Long Range
Short Range
WAN
LAN
PAN
GSM/CDMA
GPRS/3G
LMDS
Wi-Fi 802.11b
Wi-Fi5 802.11a/HL2
802.15.4
Bluetooth 2
Bluetooth 1 802.15.1
802.15.3
Low Data Rate
High Data Rate

WPAN requirements

Essential requirements include:

- Wireless - without line-of-sight limitations
- Low power consumption
- Optimized for power management and QoS‘
- Ad-hoc’ networking support
- Multi-device networks
- Cross-network interference tolerance
- Small size and easy integration into variety of devices
- Low cost & complexity

IEEE802.15 project (WPAN)

Project	Data Rate	Range	Configuration	Other Features
802.15.1 (Bluetooth)	1 Mbps	10M (class 3) 100M (class 1)	8 active device Piconet/ Scatternet	Authentication, Encryption, Voice
802.15.3 High Rate	22, 33, 44, 55 Mbps	30-50M	256 active device Piconet/Mesh	QoS, Fast Join Multi-Media
802.15.4 Low Rate	up to 250Kbps	10M nominal 1M-100M based on settings	Master/Slave (256 Devices or more) Mesh	Battery Life: multi-month to infinite
802.15.SG3a Alternate 15.3 PHY	>100Mbps	10M nominal	256 active device Piconet/Mesh	
802.15.2 Coexistence	Develop a Coexistence Model and Mechanisms Document as a Recommended Practice			

Summary of WPAN standards

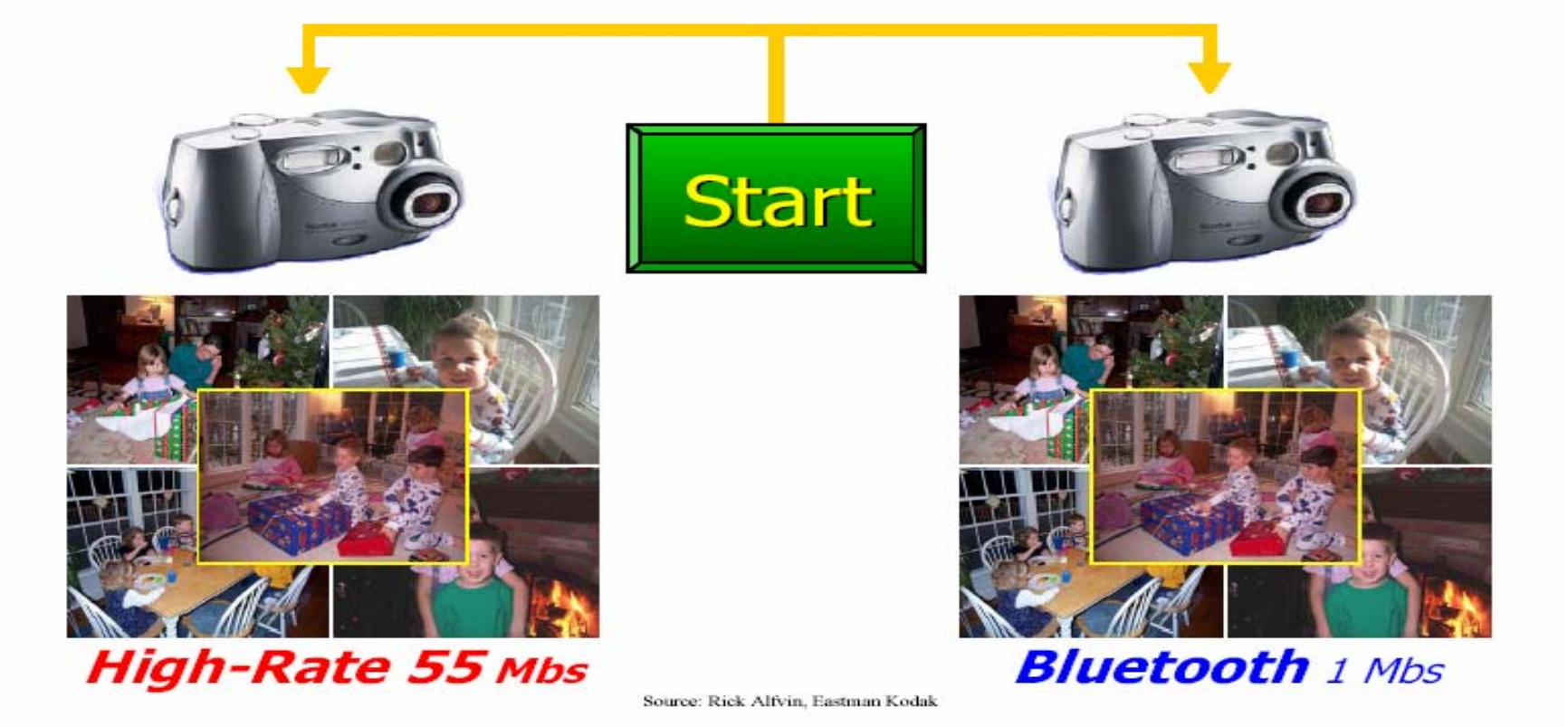
Characteristic	IEEE 802.15.4	Bluetooth	IEEE 802.11b	IEEE 802.11g+	IEEE 802.11a	IEEE 802.15.3+	UWB+ HDR
Standard version/status	IEEE approved	V 1.1 (Low-Rate)	IEEE approved	Draft	IEEE approved	Draft	Draft IEEE 802.15.3a
Max. data rate	250 kb/s; 40 kb/s; 20 kb/s	1 Mb/s	11 Mb/s	54 Mb/s	24 Mb/s mandatory; 54 Mb/s optional	11 Mb/s (QPSK) – 55 Mb/s (64 QAM) mandatory: ≥ 22 Mb/s	110 Mb/s (10m) 200 Mb/s (4m) (mandatory) (higher data-rate might optionally apply)
Max. distance	30 m	10 m	100 m	100 m	50 m	10 m	10 m
Frequency allocation	868–868.6 MHz; (ISM EU) 902–928 MHz; (ISM US) 2400–2483.5 MHz (ISM)	2.4 GHz (ISM)	2.4 GHz (ISM)	2.4 GHz (ISM)	5-GHz UNII (5.15 – 5.35 + 5.725 –5.825) GHz	2.4 GHz (ISM) 2.4–2.4835 GHZ	3.1–10.6 GHz
Channel bandwidth	0.3 MHz; 0.6 MHz (2 MHz spacing); 2 MHz (5 MHz spacing)	1 MHz	25 MHz	25 MHz	20 MHz	15 MHz	Min. 500 MHz Max. 7.5 GHz
Number of RF channels	1; 10; 16	79	3	3	12 U.S. 8 EU 4 Japan	5	(1–15)
Modulation type	BPSK; OQPSK	GFSK	11Mbaud QPSK (CCK coding)	OFDM 64 + CCK (legacy)	COFDM BPSK, QPSK, 16 QAM	DQPSK 16/32/64 QAM	BPSK, QPSK
Spreading	DS-SS	DS-FH	CCK	OFDM	OFDM	—	(Multiband)

Maximum allowed RF power	US 1W +6dB antenna gain; (FCC 15.247); EU (868 MHz) ERC70-03E: 25mW if duty cycle < 1% in 1 hour; (2400 MHz) ETSI 300-328: 20 mW[1] (2 MHz channels @ 10 mW/MHz) Japan 10 mW/MHz	0 dBm 20 dBm	US 30 dBm (PC needed for emissions> 20 dBm) EU 20 dBm Japan 10 dBm	US 30 dBm (PC needed for emissions >20 dBm) EU 20 dBm Japan 10 dBm	50 mW; 250 mW; 1-watt (depending on the used channels within the band)	US 50 mV/m (@3m, 1 MHz res. bandwidth) (47 CFR 15.249) EU 100 mW[2] EIRP (ETS 300–328) Jap 10 mW (ARIB STD-T66)	–41.3 dBm/MHz (max. average EIRP over entire band = 0.562 mW) (FCC First Report and Order; Part 15 ET Docket 98-153)
Required receiver sensitivity	–85 dBm PER<1%	–70 dBm BER < 10^{-3}	–76 dBm BER< 10^{-5} FER = 8×10^{-2}	From –76 dBm (22 Mb/s) to –74 dBm (33 Mb/s) FER = 8×10^{-2}	From –82 dBm (6 Mb/s) to –65 dBm (54 Mb/s) BER < 10^{-5}	From –82 dBm (DQPSK) to –68 dBm (64 QAM)	—
Approx # PHY power consumption	< BT	BT (~ 40–100 mW)	~4BT	~4BT	~6BT	—	(~2–3BT)
Approx cost#	~0.5 BT	BT (~ 5$)	~4BT	~4BT	~5BT	—	(~1–2BT)

• Acronyms used: BT = reference Bluetooth device, CCK = complementary code keying (CCK), orthogonal frequency-division multiplexing (OFDM), COFDM = coded OFDM, ISM = industrial, scientific, medical, PC = power control, PSDU = PHY service data unit (payload), UNII = unlicensed national information infrastructure.
+ These specifications are currently (April 2003) under drafting. All parameters mentioned are speculative, in particular some of those referring to IEEE 802.15.3a, which is in its early stages of discussion.
# Parameters referring to power consumption and cost can vary dramatically from design to design; these numbers are only to be considered as rough indications.
[1] IEEE 802.15.4 EU general equipment plans to use 1–10 mW. [2] IEEE 802.15.3 EU general equipment plans to use 8 dBm.

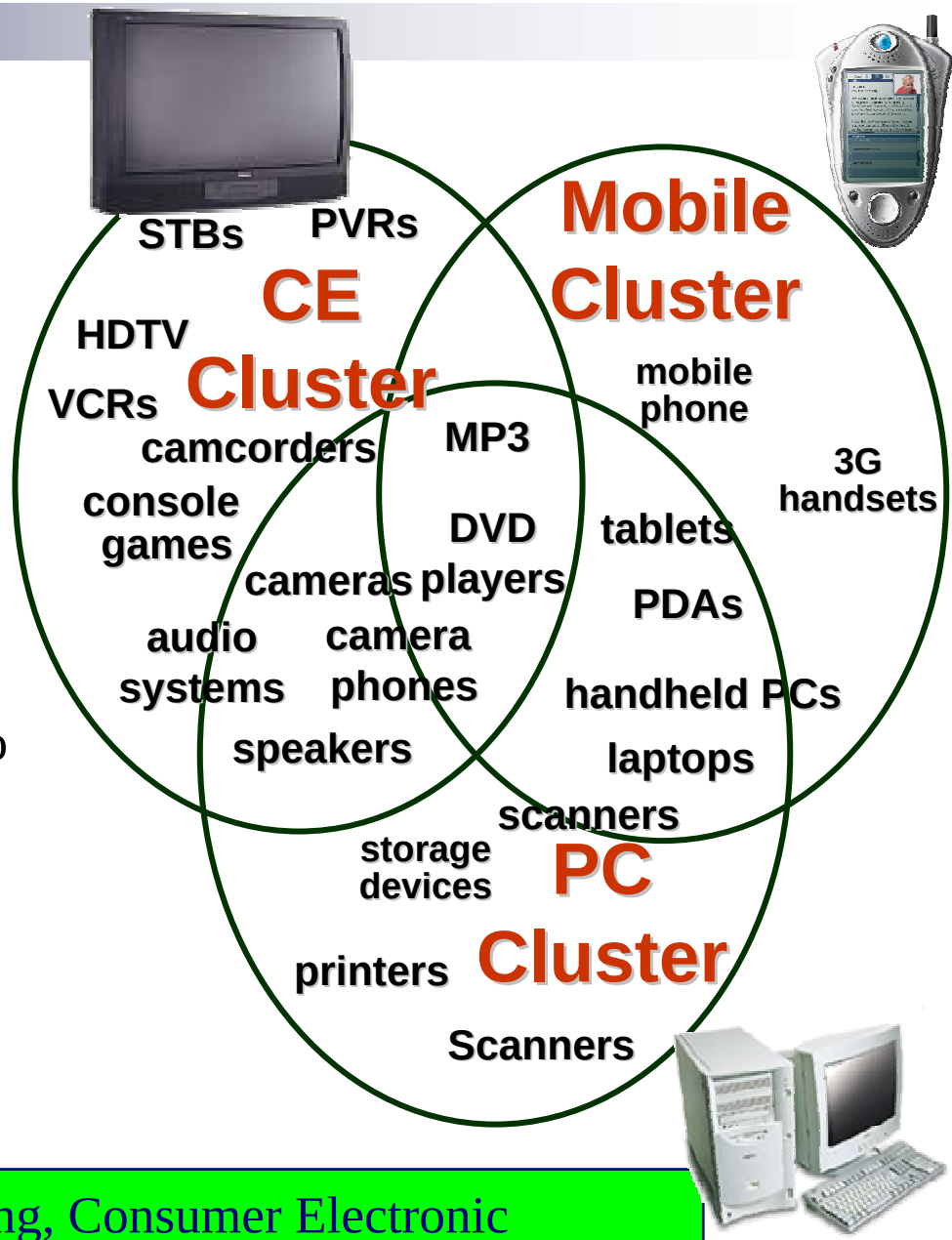
. *Summary of characteristics of some leading WLAN/WPAN standards.*

Example: transfer rate



UWB Application : WPAN

- Desktop and Laptop PCs
  - High res. printers, scanners, storage devices, etc
  - Connectivity to mobile and CE devices
- Mobile Devices
  - Multimedia files, MP3, games, video
  - Personal connectivity
- CE Devices
  - Cameras, DVD, PVR, HDTV
  - Personal connectivity



One PHY for Personal Computing, Consumer Electronic and Mobile, Wireless Personal Area Connectivity

HW

- Define UWB, features, and benefits.
- Describe the potential application of UWB for WPAN

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Thank you!

- Q&A’s