Mobile Ad-hoc and Sensor Systems

MASS 2005

Standardization Activities

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Personal Profile
Patrick Kinney

Patrick Kinney (pat.kinney@ieee.org) is the president and CTO of an independent consulting company (*Kinney Consulting LLC*) specializing in Wireless Communications and serving both large and small companies for their wireless needs. Previously he was a Vice President of Communication Technologies at Invensys responsible for directing communication efforts throughout Invensys's divisions. He received a Bachelors of Science in Electrical Engineering from the University of Notre Dame, Notre Dame Indiana. He has 29 years experience in the design, development, and deployment of communication systems and products. He is the co-Vice Chair and Secretary of the IEEE 802.15 Working Group for Wireless Personal Area Networks and the chair of the IEEE 802.15.4a Task Group. He is also the Secretary of the ZigBee Alliance and its Gateway Working Group Chair.

What are Standards?

- Agreed upon methodologies or interfaces
- Critical in communications for coexistence and interoperability
- Needed by marketplace for it to reach its full potential
- Standards are market driven, they are not for technologies searching for a market!

Why are Standards Important?

- Enable a market
- Give credibility to market
- Vendors with multiple customers
- Users with multiple vendors
- Give longevity to market

Who needs Standards?

- Why not proprietary?
  - Design
    - Standards are defined and written by experts from many different companies and backgrounds
  - Review
    - Before standards are approved they are reviewed by a diverse collection of experts
  - Maintenance
    - Standards are expensive to maintain and will excessively burden even the biggest companies

Who needs Standards?

- Why not let Forums develop the Standard?
  - Subverting the system

  “We’ll just develop this as an adhoc standard and then bring it back to the IEEE to get it formally approved”
    - Time savings are seldom realized
      - Bluetooth SIG was announced February 1998 with v1.2 released Nov 2003 (Ericsson started project in 1994)
  - Cost of maintenance
    - Standards are seldom perfect at release and often need two to three revisions to satisfy the market
  - Cost of variations
    - There is no “one solution” to a diverse marketplace; amendments to the standard keep the standard relevant
  - International Acceptance

How Do Standards Get Developed?

- Can I get my proprietary protocol turned into a standard?
  - Yes but it only rarely happens
  - Many start off using a proprietary protocol as a baseline but almost always end up significantly different

What Problems Face Standards?

- Best
  - Standards should meet the needs and expectations of the marketplace; they need not be the best
- Better
  - Being better is only important if all requirements are met and if all other characteristics are similar

What Problems Face Standards?

- Cost
  - Cost and Price are very different!
  - Successful standards need to understand the cost expectations of the market but cannot violate Fair Trade
  - It is important to understand not only the present costing but the future trends as well

What Problems Face Standards?

- Time to Market (TTM)
  - TTM is important when the standard is necessary to develop a market or when the market is ready for significant growth
  - There will always be a new technology that is very promising but needs more time
  - The cost to each company to develop a standard is proportional to the time that it takes to complete it (~2-3 MM & $20K expenses per year)

What Problems Face Standards?

- Existing conflicts
  - Companies that have existing proprietary products/systems are prone to either want the proprietary standard to be the worldwide standard or for the standard development to go slow

What Problems Face Standards?

- Unreasonable Expectations
  - Short development times
  - “one size fits all”
  - Perfect fit for a very specific application
  - Very small or limited markets

What Problems Face Standards?

- Intellectual Property (IP)
  - Getting rich off of royalties from IP mandated by standards is unrealistic but problematic
  - Understanding what IP is in which proposal is very difficult and cannot be guaranteed
  - IEEE allows IP in standards but requires that IP to be justified

What Problems Face Standards?

- Coexistence
  - Often the problem is too many different standards occupying the same frequency band
  - IEEE now requires a Coexistence Assurance document for each new standard
- Interoperability
  - Between standards is difficult without compromising performance

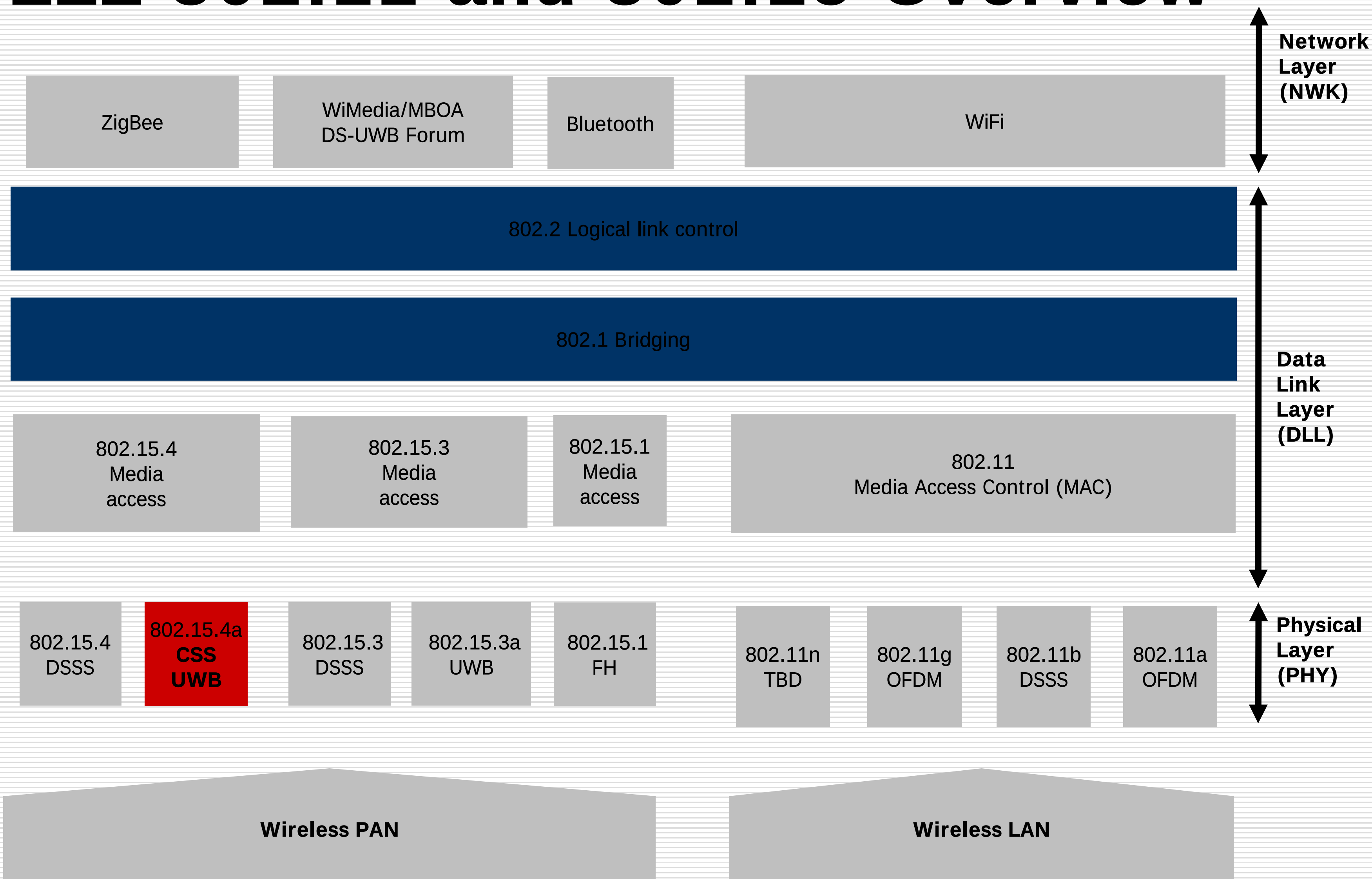
How Long Does a Standard Take to be Developed?

- Somewhere between Two and Eight Years
  - Quicker developments are the result of good market focus and understanding
  - Longer developments are typically the result of not agreeing upon the marketplace needs and rival proposals

What About Current Standards?

- IEEE 802.11n
- IEEE 802.15.4
- ISA SP100
- IEEE 1451.x

IEEE 802.11 and 802.15 Overview



IEEE 802.11x

- Focused on wireless equivalent of local area networks such as 802.3, etc.
  - Higher throughputs
  - Interoperability with other networks
  - Hand-offs
- Strategic partnership with WiFi Alliance

IEEE 802.11x

- TG11n
  - Higher data rates
  - Higher throughput
  - MIMO
  - Expect Release by end of 2006
- TG11s
  - Mesh networked Access Points
  - Target is up to 32 Access Points
  - Expect release in early 2007

IEEE 802.15.3/3a/3b/3c

Multimedia application WPAN with high throughputs and QoS

- IEEE 802.15.3a
  - Permanently deadlocked between OFDM-UWB and DS-UWB
- IEEE 802.15.3b
  - MAC revisions with expected release in 2006
- IEEE 802.15.3c
  - >60 GHz PHY, expect release in 2007/8

IEEE 802.15.4

- Focused on networks where the focus is on ad-hoc topologies and remote sensor and control systems
- Strategic partnership with ZigBee Alliance

Ongoing efforts are:

- TG4a
- TG4b

New 802.15.4a Applications

- Applications requiring robustness or fewer retransmissions in multipath environments, such as:
  - Industrial monitoring
  - Industrial mission-critical
  - Airplanes
  - Ships / engine rooms
- Applications requiring mobility faster than 11 mph, such as:
  - Drive-by Automated Meter Reading (AMR) and Drop boxes
  - Tire pressure
- Applications requiring location-awareness, such as:
  - Asset tracking (active RFID)
  - Personnel tracking
  - Motion detection

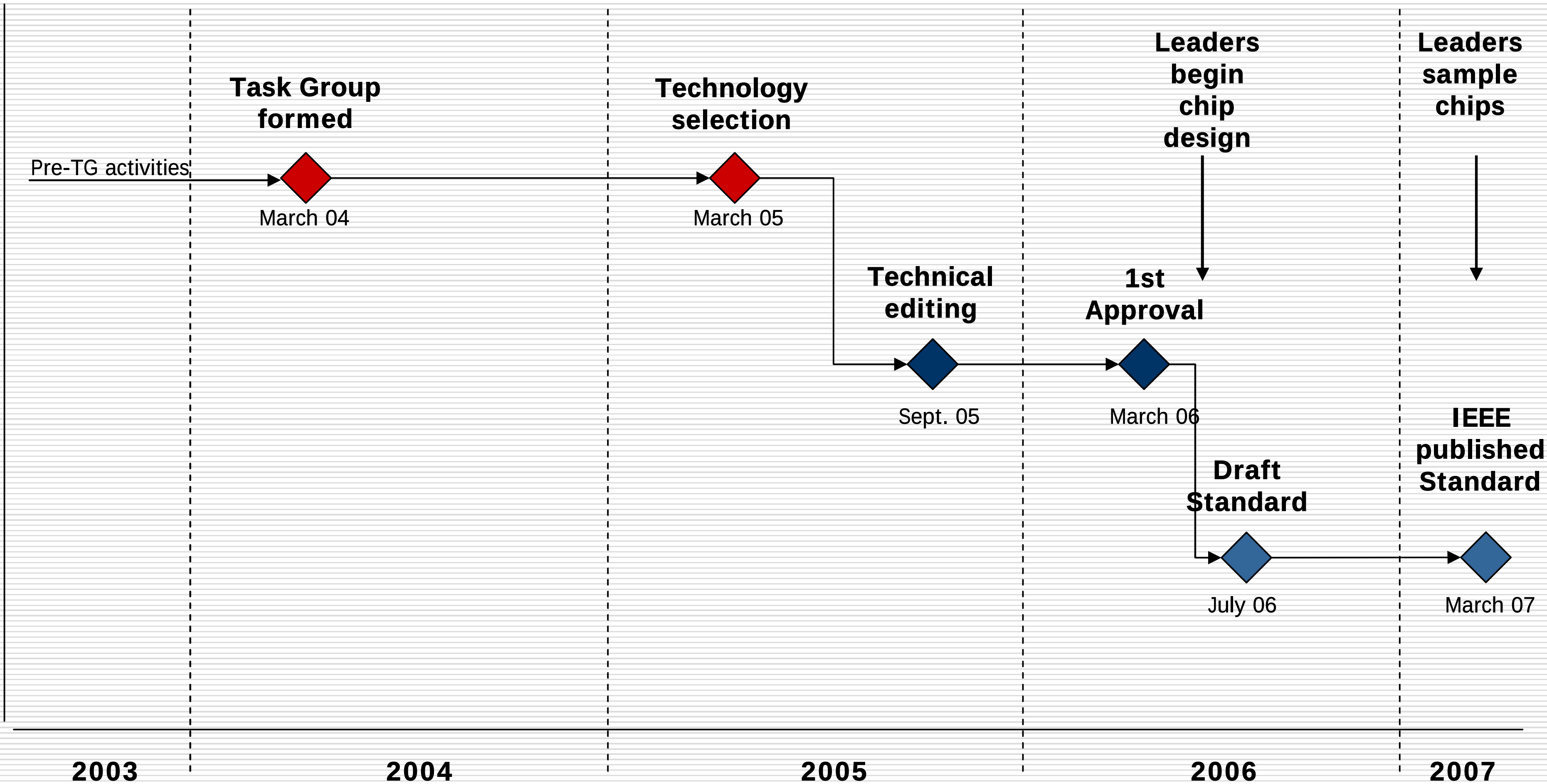
New 802.15.4a Applications

- Applications requiring extended range, such as:
  - Meter Reading
  - Building Automation
  - And other longer-range applications where repeaters are not practical
- Applications requiring low latency, such as:
  - Human interface and control devices

802.15.4a Background

- TG4a is driven by the market need to support ZigBee-type applications in more challenging RF environments, as well as adding Location Awareness.
- The IEEE 802.15.4a project will define an alternative PHY clause for an international data communication standard to amend the 802.15.4 standard with:
  - Precision Ranging
  - Extended Range
  - Enhanced Robustness
  - Enhanced Mobility
- Will use the 15.4 MAC
- Will have two PHY options:
  - 2.4 GHz CSS
  - UWB

802.15.4a Rough Timeline



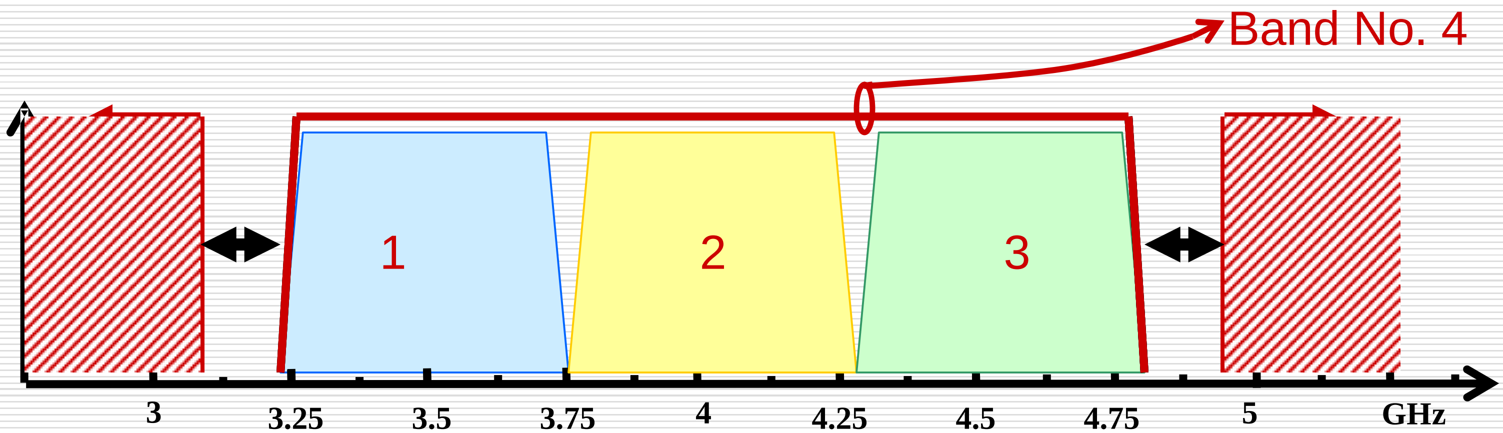
UWB PHY Technology

UWB PHY Main Features

1. Impulse-radio based (pulse-shape independent)
2. Support for different receiver architectures (coherent / non-coherent)
3. Flexible modulation format
4. Support for multiple rates
5. Enables accurate ranging/positioning
6. Support for multiple SOPs

UWB Frequency Plan

Band No.	Bandwidth (MHz)	Low Freq. (MHz)	Center Freq. (MHz)	High Freq. (MHz)
1	520	3224	3484	3744
2	520	3744	4004	4264
3	520	4264	4524	4784



Note: This plan has equal margins to 3.1 GHz & 4.9 GHz frequencies

Modulation: PRF 62 & 494 MHz

Common Data Protocol : Coherent/Non-Coherent

PRF_{Peak} = 61.750

Bits					Output
00	+--+-++-	00000000	00000000	00000000	0
01	-++-+--+	00000000	00000000	00000000	0
10	00000000	00000000	+--+-++-	00000000	1
11	00000000	00000000	-++-+--+	00000000	1

1. Unequal error protection on the 2 bits: bit 1 is similar to BPSK, bit 2 is 3 dB inferior to BPSK

2. Coherent Rate is higher than non-coherent rate.

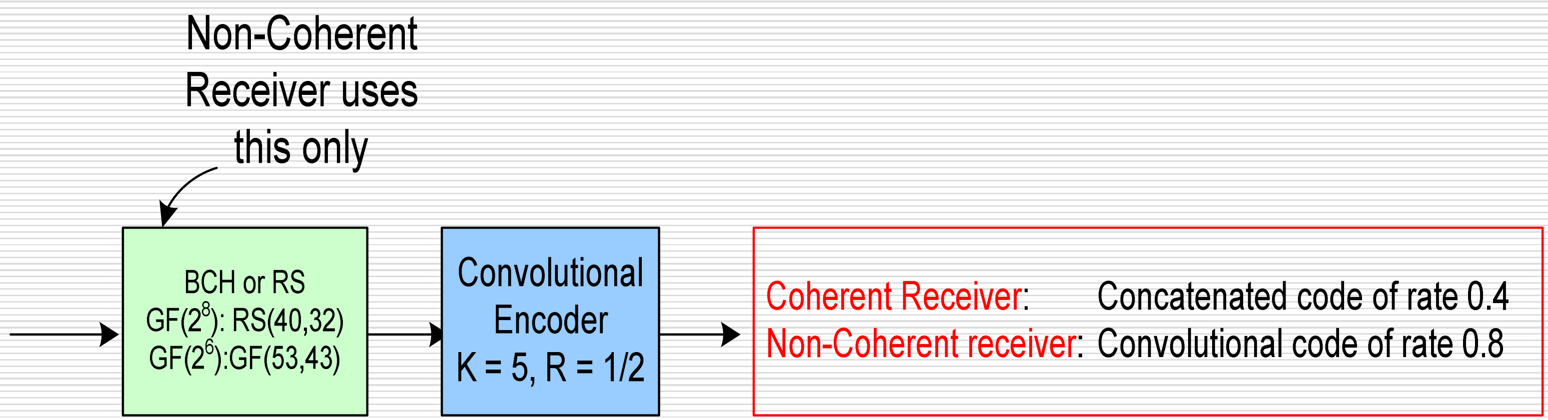
PRF_{Peak} = 494 (cell width: 16.2 ns)

Bits																	Output
00	s	0	...	0	0	0	...	0	0	...	0	0	0	...	0	0	0
⋮																	
00	0	0	...	0	s	0	...	0	0	...	0	0	0	...	0	0	0
01	-s	0	...	0	0	0	...	0	0	...	0	0	0	...	0	0	0
⋮																	
01	0	0	...	0	-s	0	...	0	0	...	0	0	0	...	0	0	0
10	0	0	...	0	0	0	...	0	s	...	0	0	0	...	0	0	1
⋮																	
10	0	0	...	0	0	0	...	0	0	...	0	0	s	...	0	0	1
11	0	0	...	0	0	0	...	0	-s	...	0	0	0	...	0	0	1
⋮																	
11	0	0	0	0	0	0	0	0	0	0	0	0	-s	0	0	0	1

0 = 00000000
s = +--+-++- (example only)

Predetermined position scrambler to improve SOP

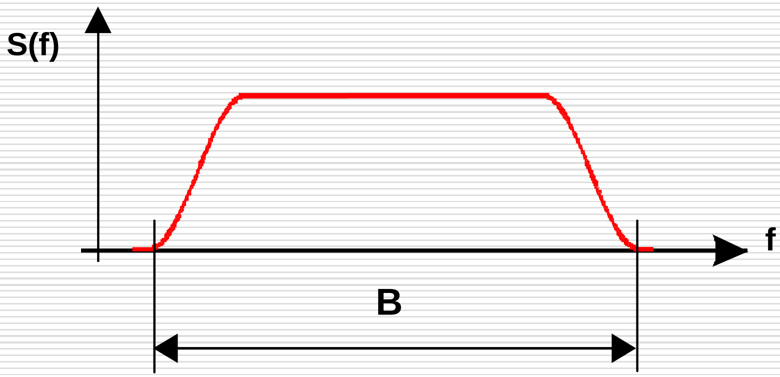
FEC (two concatenated codes)



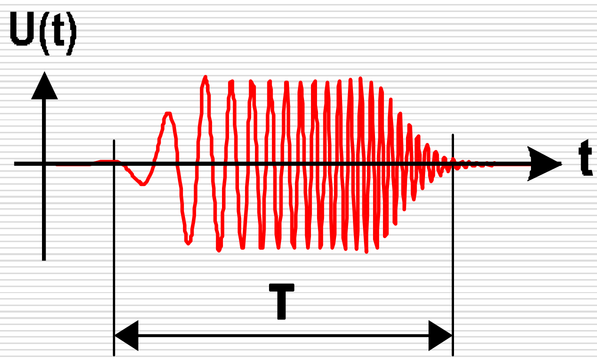
CSS PHY Technology

Characteristics of Chirp Pulses

A chirp pulse is a frequency modulated pulse



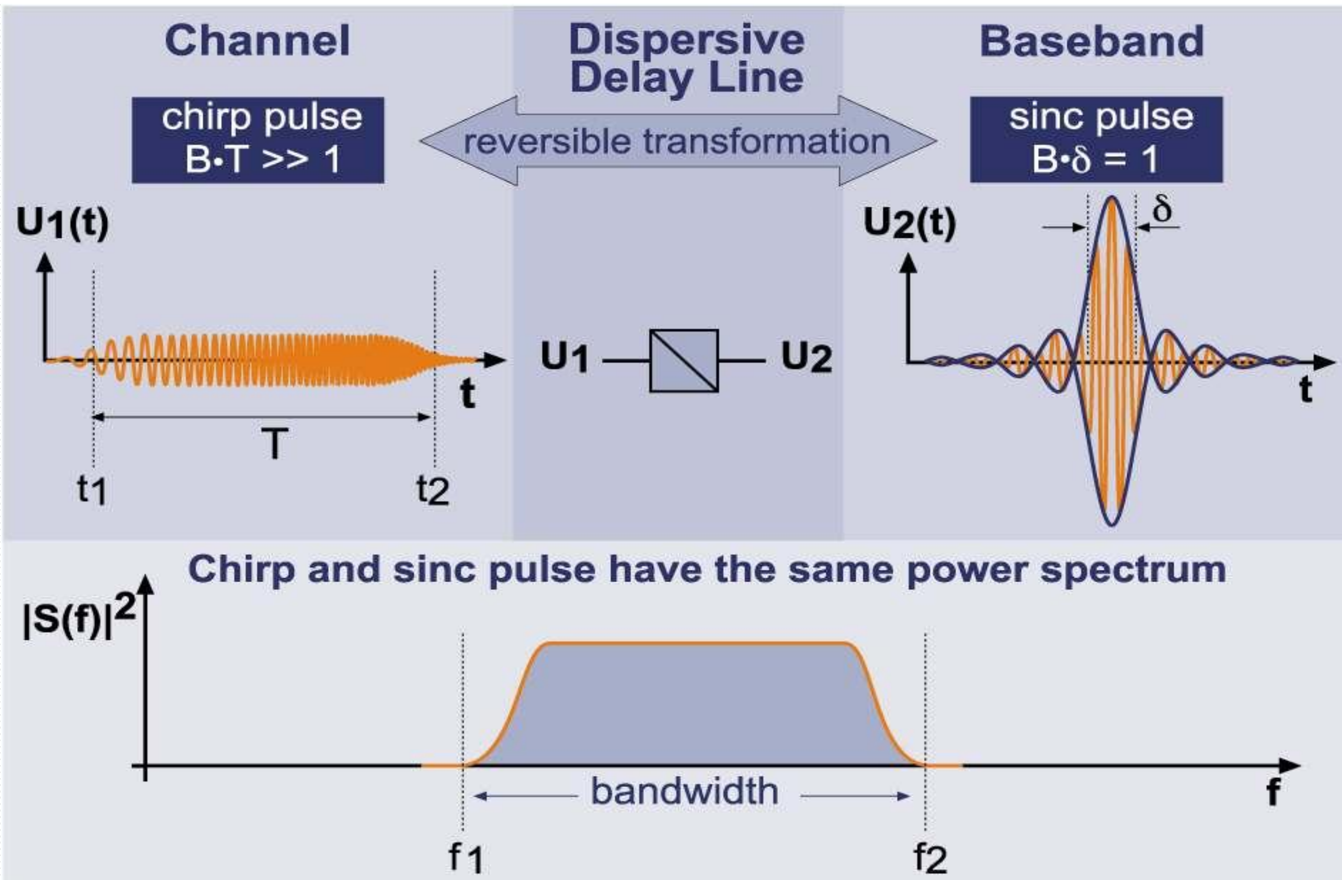
Spectrum of the chirp pulse with bandwidth B and a roll-off factor of 0.25



Up-Chirp in the time domain (roll-off factor 0.25)

Chirp Spread Spectrum: CSS

Has optimal signal forms for both RF link and baseband



Key CSS PHY Parameters

- Chirp Spread Spectrum (CSS) combined with DPSK
  - Four sub-chirps form one chirp symbol
  - Four sequences of sub-chirps form a set of four chirp symbols (equivalent to four codes)
  - Chirp symbols are separated by time gaps of alternating duration
  - Average chirp symbol rate is 1/6μs
- Two bi-orthogonal codes yield two data rates
  - Code rate 3/4 -> 3/4 * 8 bit / 6μs = 1 Mb/s
  - Code rate 6/32 -> 6/32 * 8 bit / 6μs = 250 kb/s
- Tx Power range similar to 15.4-2003, 2.4GHz
- 6 dB bandwidth is 14 MHz
- Frequency channel scheme from 802.11b (5MHz spacing)

CSS Benefits for WPAN

- One radio: The flexibility and robustness of CSS enable many mobile WPAN applications while, reducing cost and power consumption.
- Reflective environments:
  - Industrial
  - Automotive sensors and networking
  - Lighting
- Medical applications, patient sensor monitoring:
  - Low transmit power and extremely even spectrum minimize human exposure
  - Long battery lifetime

New 802.15.4 Developments: TG4b

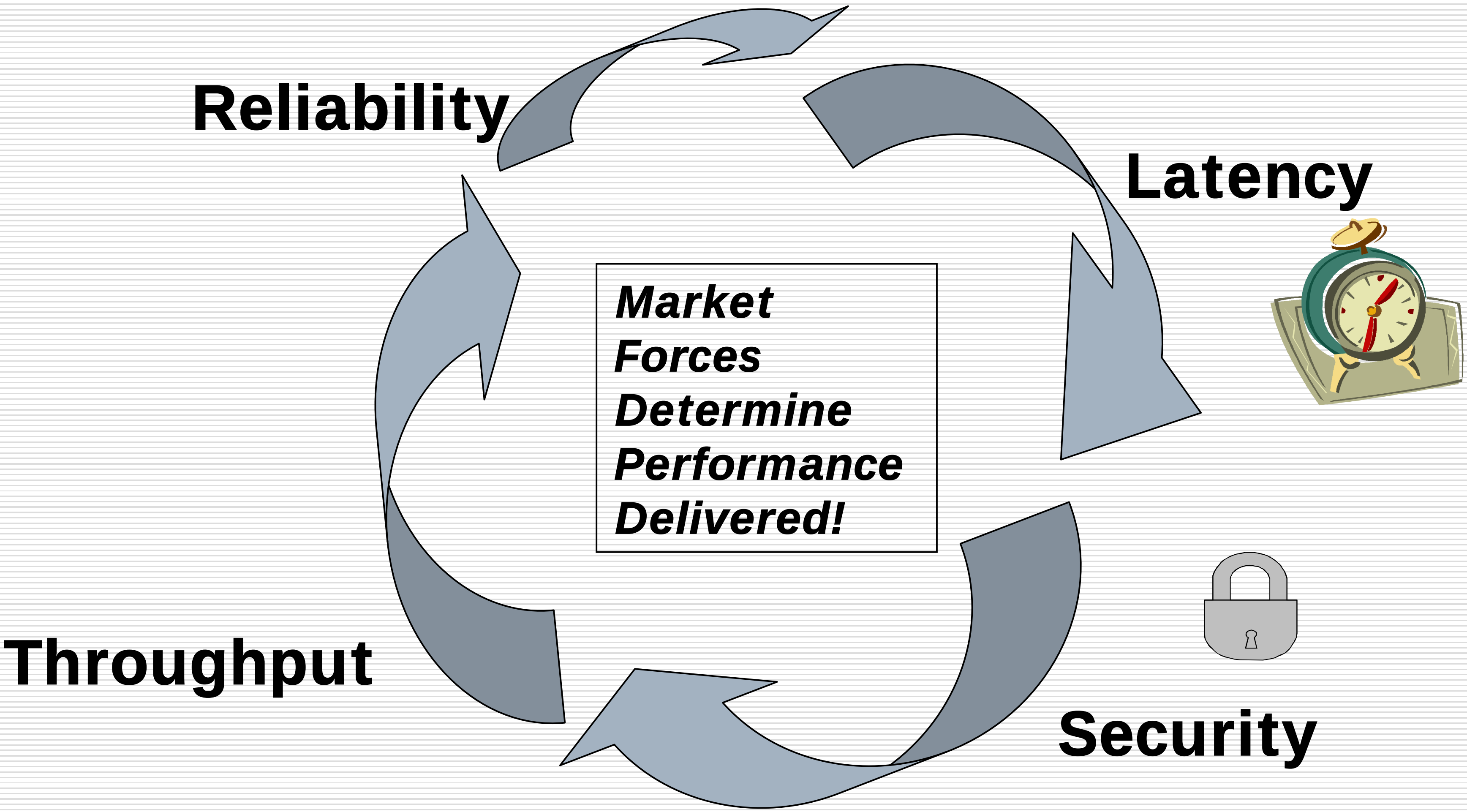
- Purpose
  - MAC Enhancements including distributed clock, enhanced security, reduced complexity, and correcting edge condition issues
  - PHY Enhancements such as high data rate for <1 GHz bands
- Schedule
  - 1st draft complete by Nov 05
  - Sponsor Ballot by May 06
  - Release by Nov 06

ISA: SP100 Industrial Wireless Networks

- Sensor and Control networks for the Industrial Environment
- Partnered with WINA

Following slides courtesy of Wayne Manges, SP100 Chair

Technologies Exploding – Balance Needed



Leveraging Defense and Commercial Wireless For Industrial Applications

- Reliability -
  - Mesh – Billions of $ from DOD
  - Spread Spectrum (FHSS, DSSS) and Ultra-Wideband
- Power
  - Harvesting – vibration, RF, PV
  - Low-power Designs – ASICs, FPGAs, DSP
  - Protocols – Low-duty cycle – ZigBee
- Security
  - Encryption – AES, WPA, WEP
  - Physical – RF layer, FIPS 140-2
  - Integrated – impacts on throughput, latency, reliability

Standards – Maximum Impact

ISA/WINA/DOE Impact on Standards – permit introduction of entire suite of wireless products from many vendors supporting the "ubiquitous sensing" model in vision.

- **SP100 proposes a standardized methodology to**
  - **Assess environment – light to harsh, RF, et al**
  - **Assess application – latency, throughput, etc**
  - **Assess options – technologies, products, standards**
  - **Assess deployment – initial stability, ease**
  - **Assess performance – against requirements**
  - **Maintain – tools, costs, upgrades**

Standards – Results Focus

SP100 efforts will result in standards, recommendations, and technical reports focused on assuring successful wireless deployments in industrial environments.

- **SP100 Compliance will assure:**
  - **Supplier Specifications are consistent and easy to interpret**
  - **User Requirements are succinct, relevant and easy to interpret**
  - **Options are clear and easily differentiable**
  - **Probable outcomes are quantitatively evaluated against options**

SP100 - Success Oriented

SP100 efforts will leverage other standards, as appropriate, to produce a relevant result in as short a time frame as possible.

- **SP100 Leverages:**
  - **SP99 - Security**
  - **IEEE 1451 – Smart Sensor**
  - **FIPS 140-2 – Security**
  - **ISO/OSI model for network connectivity**
- **SP100 Encourages**
  - **New technology**
  - **Deployment**
  - **Communication among practitioners**

Remaining Risks

- Technical – security, latency, reliability
- Commercial – acceptance, cost, marketing
- Political – assumptions of either too hard or too easy

Solving a multi-disciplinary problem!

- Wireless – radio, packaging, antenna
- Industrial – harsh environment, fault tolerant, safety related, cost
- Sensor – filters, sampling, sensitivity, interferers, controls
- Networks – real-time, latency, throughput, security, integrity, vertical integration

IEEE 1451.x: Smart Sensor Interface

- IEEE P1451.1 defines a common object model description for transducers and a network capable application processor (NCAP) for network interfacing
- IEEE P1451.2 defines a transducer electronic data sheet (TEDS), smart transducer interface module (STIM) and transducer independent interface
- IEEE P1451.3 defines a multi-drop sensor data network based on an RF-spread-spectrum-in-wire physical medium
- IEEE P1451.4 defines a physical connection (Mixed-Mode Interface, or MMI) that is alternately used for TEDS data and analog signals, on either 2, 3 or 4 wires
- IEEE P1451.5 will define Wireless connectivity

What About Future Standards?

- Cognitive Radio
  - Ability to adapt to a dynamic environment and achieve optimum performance