IEEE 802.15.4

Standardized radio technology for low power personal area networks

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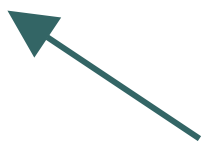
January 14, 2004

IEEE 802.15.4 Goals

- Many devices
- Small data payloads
- Long battery life is critical
- Low duty cycles
- Designed for sensors, controllers, medical monitoring, throw-away devices, etc.

- In contrast, Bluetooth:
  - Few devices
  - Single-day battery life (rechargeable)
  - Large data payloads
    - Synchronization of devices

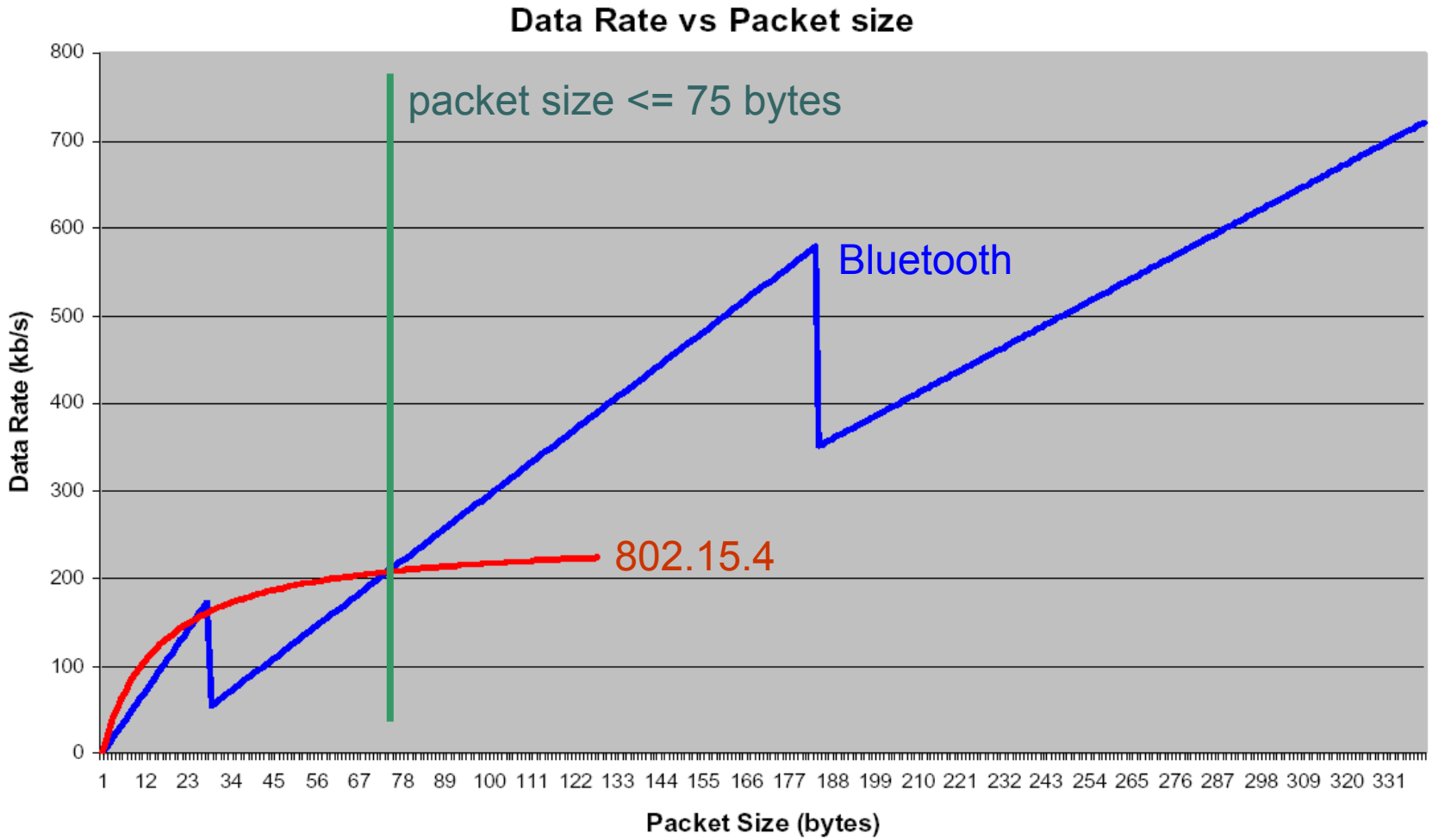


Wireless Sensor Networks

From Pat Kinney's talk at the 2003 Zigbee Open House

Comparing Industry Standards

802.15.4 vs Bluetooth



From Pat Kinney's talk at the 2003 Zigbee Open House

IEEE 802.15.4 and Zigbee

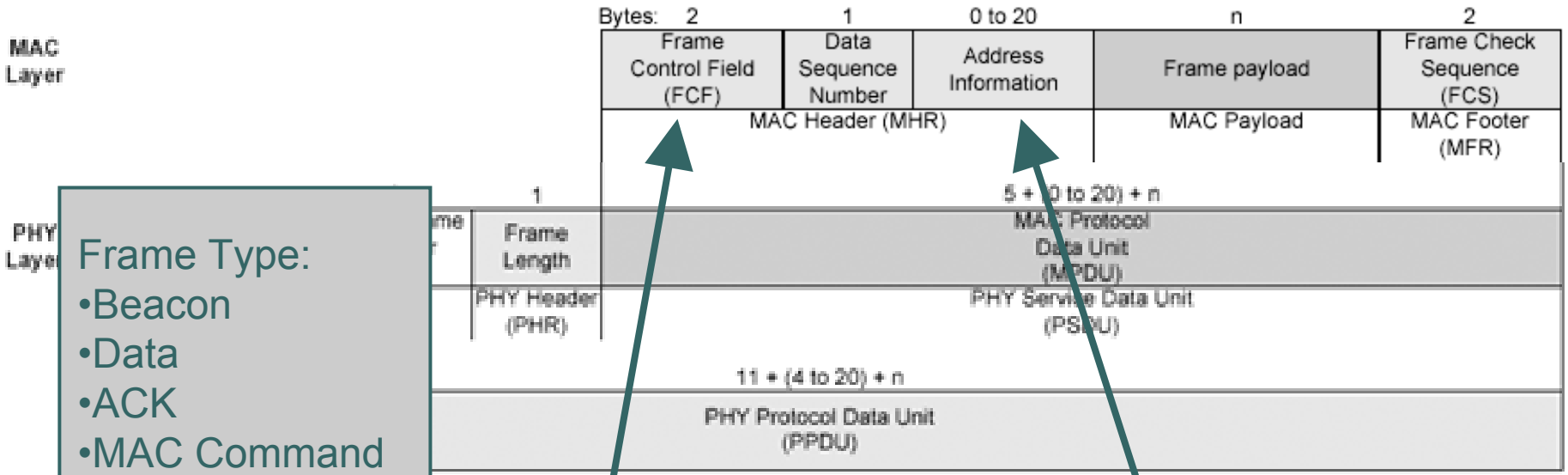
- 802.15.4
  - **PHY**sical Layer
    - Radio, transmitter, receiver
  - **M**edia **A**ccess **C**ontrol Layer
    - Radio controller, data on device
- Zigbee
  - Network Layer
    - Routing, organization, aggregation
  - Application Support Layer
    - Application APIs for data delivery
- Zigbee **requires** 802.15.4 as the underlying PHY and MAC technology

IEEE 802.15.4 PHY

- O-QPSK modulation
  - “plays nice” with 802.11a/b/g networks
  - 2400 MHz operation
  - 250 kbps data rate
- BPSK modulation
  - 868/915 MHz
  - 20/40 kbps data rate

IEEE 802.15.4 MAC

Application-controlled sequence number



Frame Type:
- Beacon
- Data
- ACK
- MAC Command

1,2, or 8 byte address source and/or destination

Bits: 0-2	3	4	5	6	7-9	10-11	12-13	14-15
Frame Type	Security Enabled	Frame Pending	Acknowledge request	Intra PAN	Reserved	Destination addressing mode	Reserved	Source addressing mode

TinyOS 802.15.4 Implementation

- Length and FCS generated by HW
- TinyOS Radio Stack:
  - Assigns FCF, DSN, and Destination
  - Adds AM type and Group to beginning of data payload
  - Adds TOS_Msg.data
- Typical overhead:
  - 8 bytes header, 2 bytes footer = 10 bytes

IEEE 802.15.4 Radio

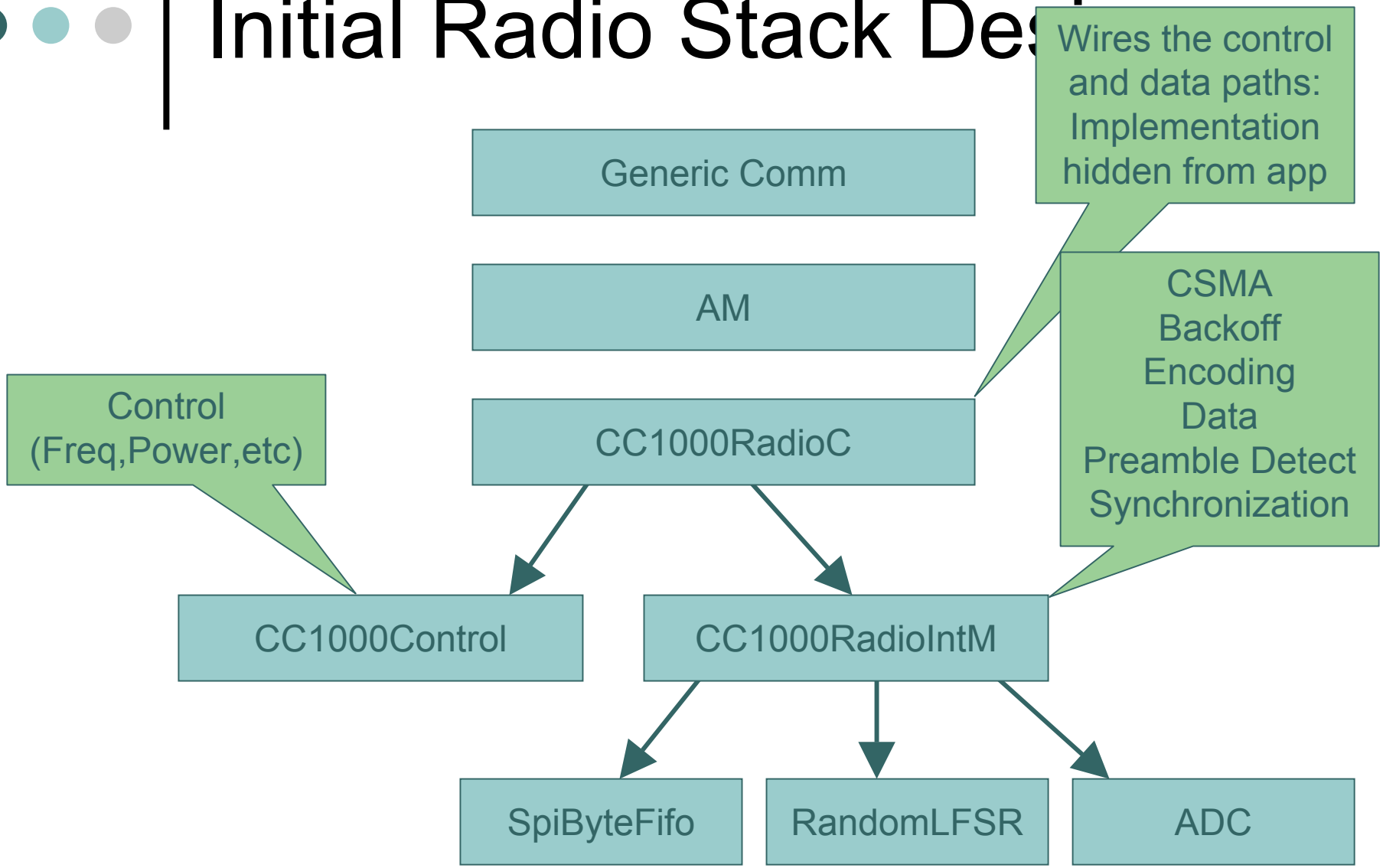
- CC2420
  - 250kbps : 2Mchip/s
  - 2.4GHz
  - Offset QPSK
  - 1.8V supply
  - 128byte TX/RX buffers

  - Full Production: Feb 2004
  - $5

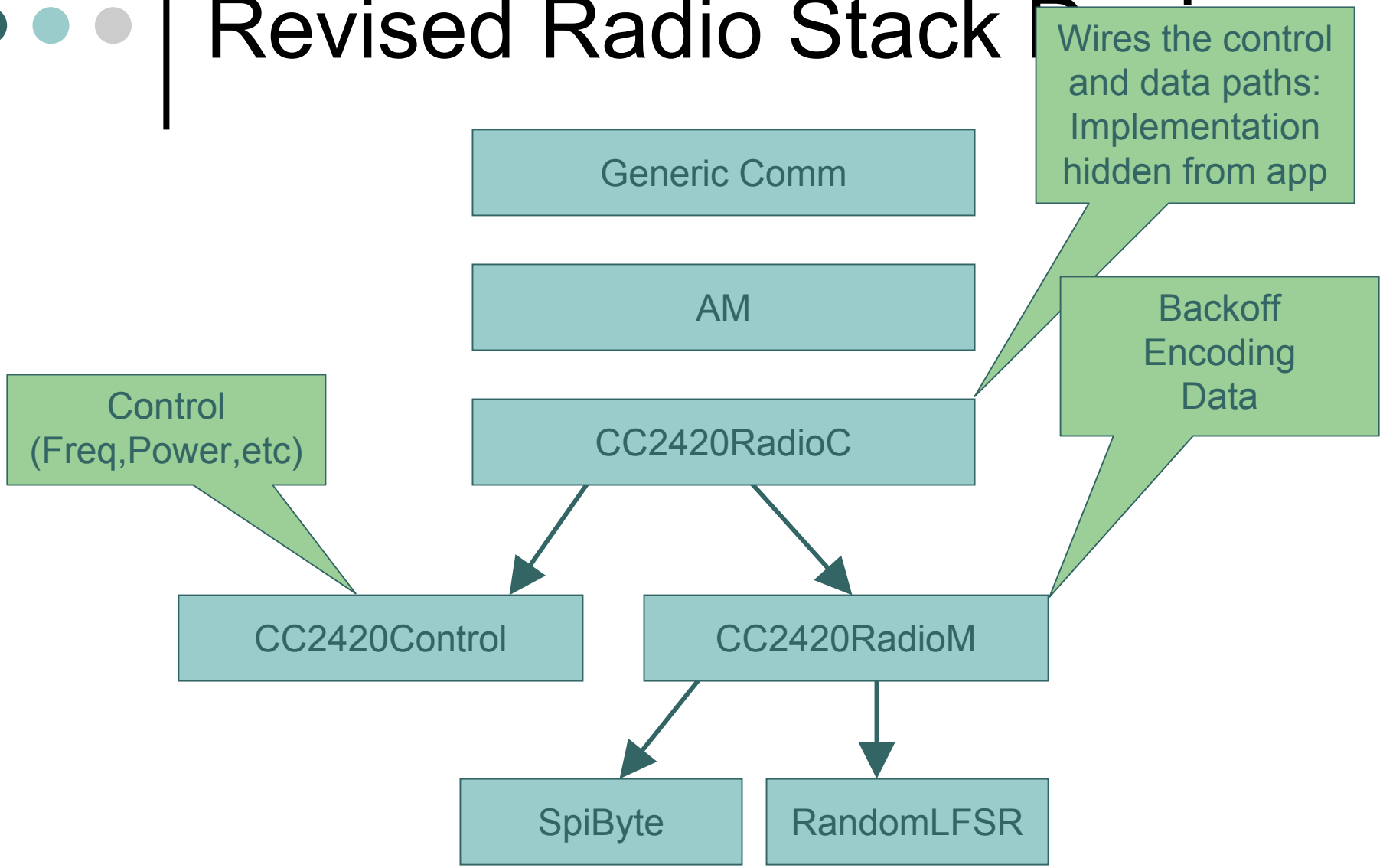
CC2420 Hardware Features

- Digital RSSI
- 128 byte RX and TX buffers
- Clear Channel Assessment
- Link Quality Indicator
  - Based on incoming signal sampled throughout the reception of the packet
- MAC Encryption
  - 128-bit with authentication
- Programmable Interrupts
  - Time Sync
  - Clear Channel
  - Oscillator Stable

Initial Radio Stack Des



Revised Radio Stack



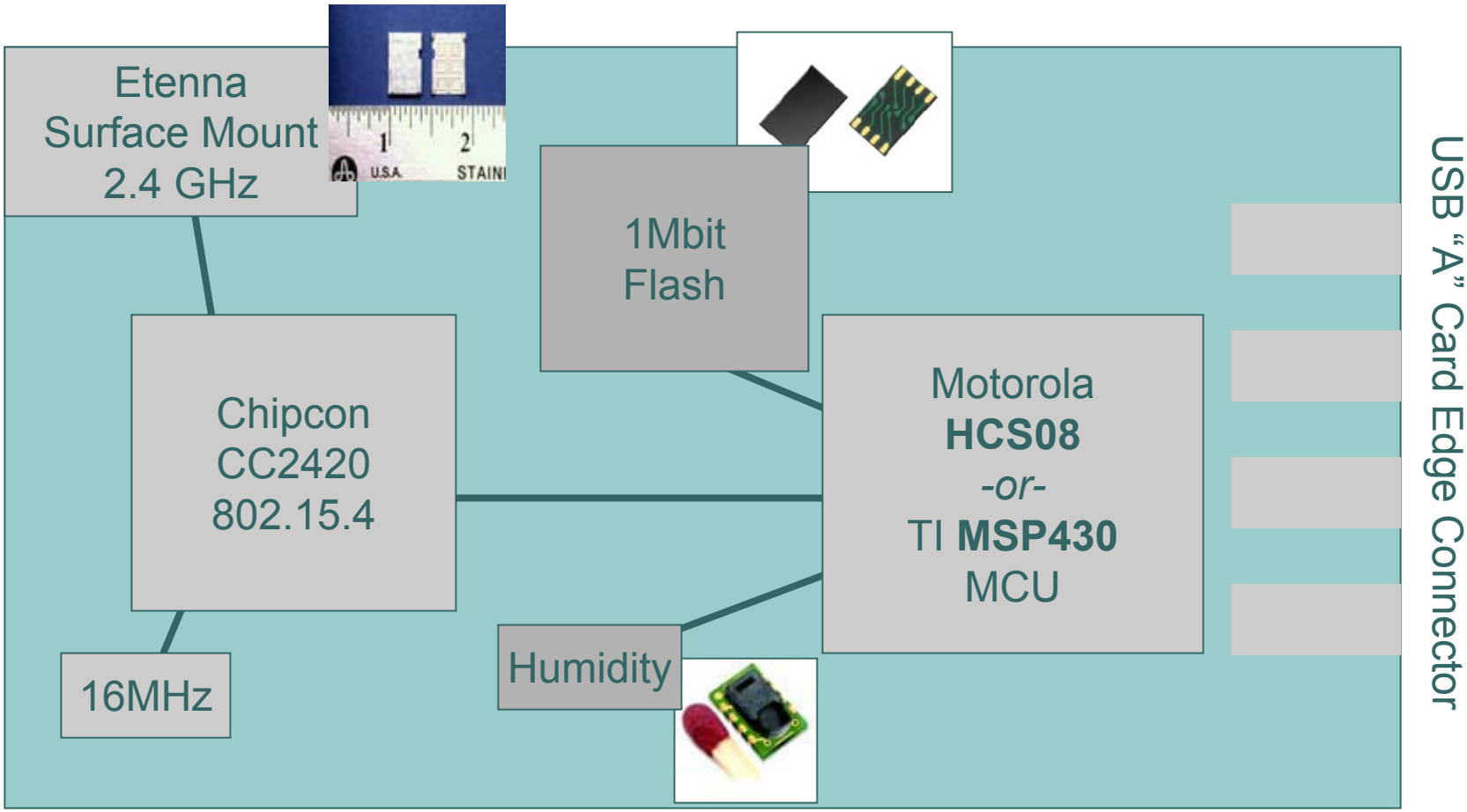
Two Options for TinyOS Community

- Telos
  - Completely new platform
  - Designed by UCB/IRB
- MicaZ
  - Mica2 with CC2420 radio
  - Designed by Crossbow

Telos

- A platform for low power research
  - Environmental monitoring
  - Building monitoring
- Long lifetime, low power, low cost, integrated sensors
- Why not the current Mica platform?
  - Oscillator start up times, oscillator noise, and operating/sleep current too high
  - Instead leverage 802.15.4 low power operation and new MCUs
- Use new standards, compare, research
  - 802.15.4
  - ZigBee networking
- Experiment with different power sources and form factors
- Single board design to assist in environmentally sealing the mote

Telos


Etenna
Surface Mount
2.4 GHz
1Mbit
Flash
Chipcon
CC2420
802.15.4
Motorola
HCS08
-or-
TI **MSP430**
MCU
16MHz
Humidity
USB "A" Card Edge Connector

MCU

Telos can have either one

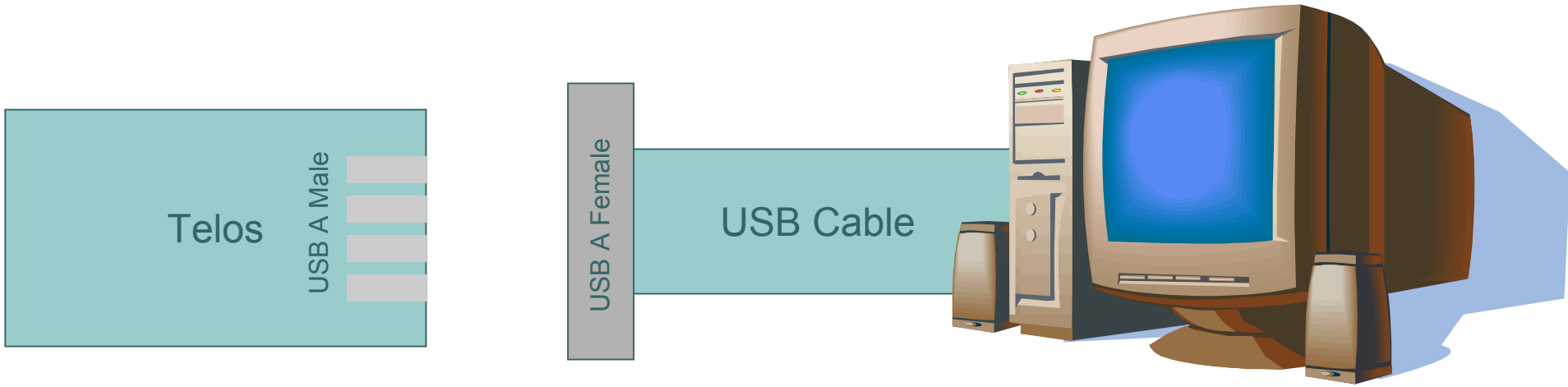
- Motorola HCS08
  - 8-bit
  - 60K ROM
  - 4K RAM
  - SCI,SPI,I^2C
  - 10-bit ADC
  - 100μs wakeup
  - 700nA sleep current
  - 1 kHz internal oscillator
  - 20 MHz internal
  - Requires Codewarrior and BDM programmer
- TI MSP430
  - 16-bit
  - 60K ROM
  - 2K RAM
  - SCI, SPI
  - 12-bit ADC
  - 6μs wakeup
  - 800nA sleep current
  - 32 kHz ext oscillator
  - 4.15 - 8MHz internal
  - Requires msp-gcc and USB port

We have TinyOS running on both MCUs

Advantages of a new MCU

- *1.8V operation*
  - Entire mote running at 1.8V could have double the lifetime of a mote using a 3.6V lithium battery
- Fast wakeup (RAM maintained)
- Time synchronization and accurate TDMA schemes (small deterministic wakeup)
- *Double-buffered* hardware SCI(UART), SPI, and I^2C bus support
- *Priority interrupts* with an external high priority IRQ line

Programming



- USB Interface
  - Programming
  - Debugging (JTAG)
  - UART communication
- No programming board
  - Easy for testbeds
  - Standardized interface