Topic 03: TinyOS and Telos

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ICTP-ITU School on Wireless Networking for Scientific Applications in Developing Countries

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TinyOS

- Reference: "The Emergence of Networking Abstractions and Techniques in TinyOS", Philip Levis, Sam Madden, David Gay, Joseph Polastre, Robert Szewczyk, Alec Woo, Eric Brewer, and David Culler, NSDI 2004.
  - Section-2
- More related to embedded computing than wireless

TinyOS Goals

- An “operating-system” for embedded sensor nodes
- Different requirements for such platforms
  - Should be designed for current & future hardware
  - Cater to a wide variety of applications
  - Limited resources: memory, power
  - Concurrency-intensive operation: data driven

TinyOS Design Overview (1 of 2)

- Modular framework:
  - A set of software components and interfaces
  - No strict definition of system/user boundary
- Issues addressed by this approach:
  - Adaptation to heterogeneous hardware
    - Reuse of software
  - Adaptation to different application requirements
    - Put together required software components
  - Memory resource constraints
    - Use only the required components

TinyOS Design Overview (2 of 2)

- Event-driven concurrency model:
  - Hardware events and software tasks
- Issues addressed by this approach:
  - Requirement for concurrency
    - Event-driven model is natural: no blocking or polling
  - Limited memory
    - Many concurrent tasks using just one stack
  - Power savings
    - No tasks ==> sleep

TinyOS Design

- Interface: a set of *commands* and *events*
  - Command: sub-routine to perform some action
  - Event: completion of request, or external trigger
    - Can be bound to a hardware interrupt
- Component:
  - *Provides* a set of interfaces (used by others)
  - *Uses* a set of interfaces (provided by others)
- An application "wires" together the interfaces of a set of components

Blink: An Example TinyOS Appln.

- Split into Blink.nc & BlinkM.nc
- BlinkM.nc:
  - The module: the actual implementation
- Blink.nc:
  - The configuration: the "wiring-up" of interfaces
- Other examples: CountLeds, CountSend, CountReceive

The Telos Platform

- Reference: "Telos: Enabling Ultra-Low Power Wireless Research", Joseph Polastre, Robert Szewczyk, and David Culler, IPSN/SPOTS 2005.
- Latest among a series of embedded sensor platforms from U.C.Berkeley/Intel

Family of Berkeley Motes

Mote Type Year	WeC 1998	René 1999	René2 2000	Dot 2000	Mica 2001	Mica2Dot 2002	Mica 2 2002	Telos 2004
Microcontroller								
Type	AT90LS8535		ATmega163		ATmega128			TI MSP430
Program memory (KB)	8		16		128			48
RAM (KB)	0.5		1		4			10
Active Power (mW)	15		15		8		33	3
Sleep Power (μW)	45		45		75		75	15
Wakeup Time (μs)	1000		36		180		180	6
Nonvolatile storage								
Chip	24LC256				AT45DB041B			ST M25P80
Connection type	I^2C				SPI			SPI
Size (KB)	32				512			1024
Communication								
Radio	TR1000				TR1000	CC1000		CC2420
Data rate (kbps)	10				40	38.4		250
Modulation type	OOK				ASK	FSK		O-QPSK
Receive Power (mW)	9				12	29		38
Transmit Power at 0dBm (mW)	36				36	42		35
Power Consumption								
Minimum Operation (V)	2.7		2.7		2.7			1.8
Total Active Power (mW)	24				27	44	89	41
Programming and Sensor Interface								
Expansion	none	51-pin	51-pin	none	51-pin	19-pin	51-pin	16-pin
Communication	IEEE 1284 (programming) and RS232 (requires additional hardware)							USB
Integrated Sensors	no	no	no	yes	no	no	no	yes

Source: "Telos: Enabling Ultra-Low Power Wireless Research", J. Polastre et. al., IPSN/SPOTS 2005.

Microcontroller Comparison

Manufacturer	Device	RAM (kB)	Flash (kB)	Active (mA)	Sleep (μA)	Release
Atmel	AT90LS8535	0.5	8	5	15	1998
	Mega128	4	128	8	20	2001
	Mega165/325/645	4	64	2.5	2	2004
General Instruments	PIC	0.025	0.5	19	1	1975
Microchip	PIC Modern	4	128	2.2	1	2002
Intel	4004 4-bit	0.625	4	30	N/A	1971
	8051 8-bit Classic	0.5	32	30	5	1995
	8051 16-bit	1	16	45	10	1996
Philips	80C51 16-bit	2	60	15	3	2000
Motorola	HC05	0.5	32	6.6	90	1988
	HC08	2	32	8	100	1993
	HCS08	4	60	6.5	1	2003
Texas Instruments	TSS400 4-bit	0.03	1	15	12	1974
	MSP430F14x 16-bit	2	60	1.5	1	2000
	MSP430F16x 16-bit	10	48	2	1	2004
Atmel	AT91 ARM Thumb	256	1024	38	160	2004
Intel	XScale PXA27X	256	N/A	39	574	2004

Fig. 4. Microcontroller history: The main table contains traditional microcontrollers; the bottom two devices are 32-bit microprocessors presented for comparison.

Source: "Telos: Enabling Ultra-Low Power Wireless Research", J. Polastre et. al., IPSN/SPOTS 2005.

Current Consumption: Comparison

Operation	Telos	Mica2	MicaZ
Minimum Voltage	1.8V	2.7V	2.7V
Mote Standby (RTC on)	5.1 μA	19.0 μA	27.0 μA
MCU Idle (DCO on)	54.5 μA	3.2 mA	3.2 mA
MCU Active	1.8 mA	8.0 mA	8.0 mA
MCU + Radio RX	21.8 mA	15.1 mA	23.3 mA
MCU + Radio TX (0dBm)	19.5 mA	25.4 mA	21.0 mA
MCU + Flash Read	4.1 mA	9.4 mA	9.4 mA
MCU + Flash Write	15.1 mA	21.6 mA	21.6 mA
MCU Wakeup	6 μs	180 μs	180 μs
Radio Wakeup	580 μs	1800 μs	860 μs

Source: "Telos: Enabling Ultra-Low Power Wireless Research", J. Polastre et. al., IPSN/SPOTS 2005.

Reduced idle current

Reduced active current

Reduced wakeup time

Lower cut-off voltage

Radio Comparison

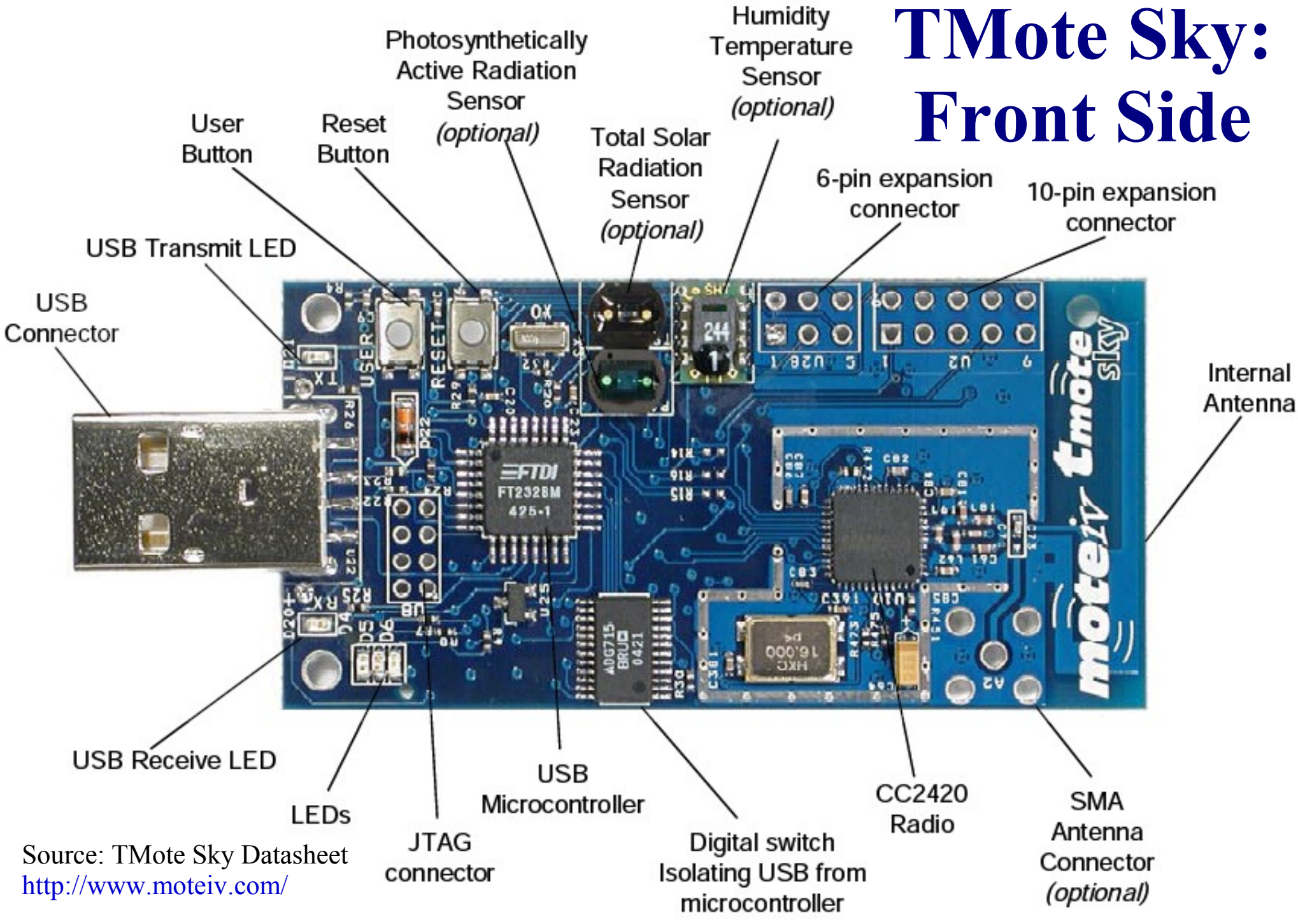
Type	Narrowband				Wideband		
Vendor Part no.	RFM TR1000	Chipcon CC1000	Chipcon CC2400	Nordic nRF2401	Chipcon CC2420	Motorola MC13191/92	Zeevo ZV4002
Max Data rate (kbps)	115.2	76.8	1000	1000	250	250	723.2
RX power (mA)	3.8	9.6	24	18 (25)	19.7	37(42)	65
TX power (mA/dBm)	12 / 1.5	16.5 / 10	19 / 0	13 / 0	17.4 / 0	34(30)/ 0	65 / 0
Powerdown power (μA)	1	1	1.5	0.4	1	1	140
Turn on time (ms)	0.02	2	1.13	3	0.58	20	*
Modulation	OOK/ASK	FSK	FSK,GFSK	GFSK	DSSS-O-QPSK	DSSS-O-QPSK	FHSS-GFSK
Packet detection	no	no	programmable	yes	yes	yes	yes
Address decoding	no	no	no	yes	yes	yes	yes
Encryption support	no	no	no	no	128-bit AES	no	128-bit SC
Error detection	no	no	yes	yes	yes	yes	yes
Error correction	no	no	no	no	yes	yes	yes
Acknowledgments	no	no	no	no	yes	yes	yes
Interface	bit	byte	packet/byte	packet/byte	packet/byte	packet/byte	packet
Buffering (bytes)	no	1	32	16	128	133	yes *
Time-sync	bit	SFD/byte	SFD/packet	packet	SFD	SFD	Bluetooth
Localization	RSSI	RSSI	RSSI	no	RSSI/LQI	RSSI/LQI	RSSI

* Manufacturer's documentation does not include additional information.

Source: "Telos: Enabling Ultra-Low Power Wireless Research", J. Polastre et. al., IPSN/SPOTS 2005.

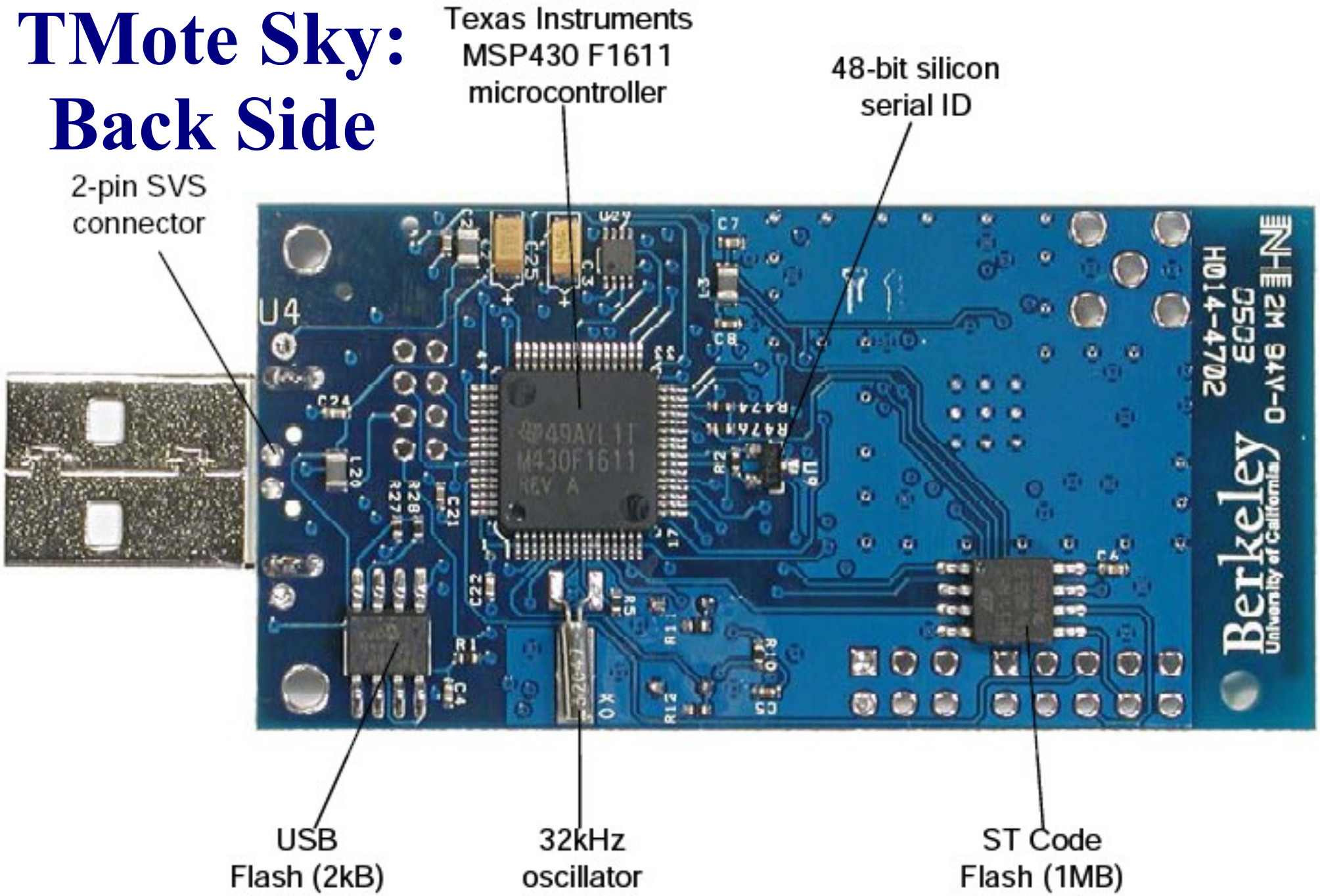
Significant aspect: wideband, noise-resilient modulation scheme

TMote Sky: Front Side



Source: TMote Sky Datasheet
http://www.moteiv.com/

TMote Sky: Back Side



Source: TMote Sky Datasheet http://www.moteiv.com/

Summary

- TinyOS:
  - Component-based OS for embedded platforms
  - Event-driven model suited to embedded sensor applns.
- Telos:
  - Hardware platform for embedded sensor applications
  - CC2420 radio (802.15.4 compliant)