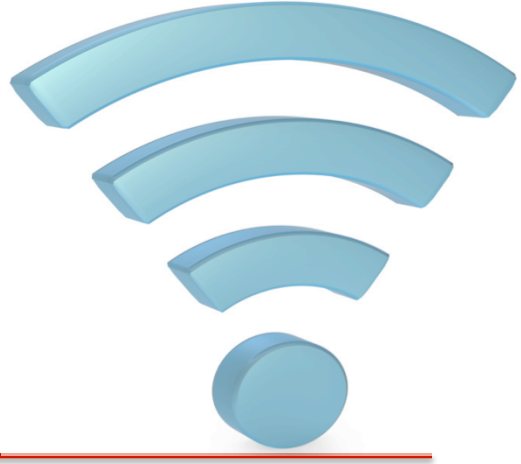
Wireless Sensor Networks



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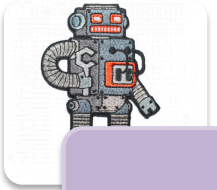
Course structure

1. lecture

- Clock, GPIO,Timer
- SPI, UART

2. lecture

- RF basics
- MRFI chat



3. lecture

- SimpliciTI protocol
- Data storage, Project

WSN: Timetable 2015

Nr:	1	2	3	4	5	6	7	8	9	10	11
date:	18.03.15	26.03.15	01.04.15	08.04.15	15.04.15	22.04.15	29.04.15	06.05.15	13.05.15	20.05.15	27.05.15
11:45 - 13:15	Intro WSN	*Intro practical training 1*	Clocks GPIO	Flash	*Intro practical training 2*	MRFI	LQI	*Intro practical training 3*	address transmission	Non volatile objects	***Exam***
13:30 - 15:00	team up	First steps / project setup	ADC Timer	UART SPI	MRFI	CRC RSSI	Simple Chat	peer to peer	Non volatile objects	Range extender	Q&A project

Room: S159

S159
Intro WSN
Intro practical
Intro practical
Intro practical
Exam

S081

S081
part 1
part 2
part 3

group	name	poject
1	1: 2:	
2	1: 2:	
3	1: 2:	
4	1: 2:	
5	1: 2:	
6	1: 2:	
7	1: 2:	
8	1: 2:	
9	1: 2:	
10	1: 2:	

Project

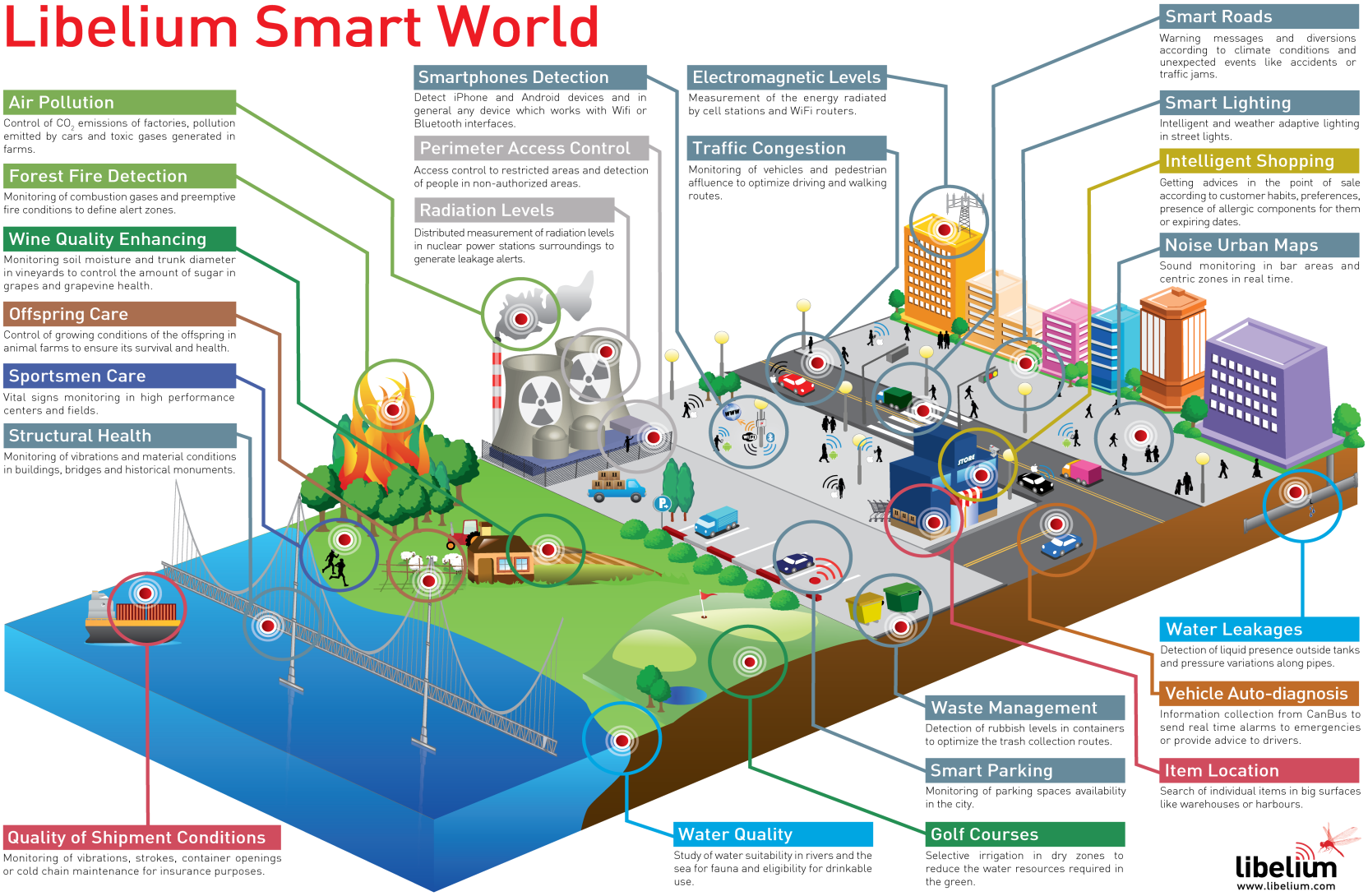
- Group of 2 – 4 students
- Minimun of two MSP430 boards
- Documentation + Code
- Presentation

Wireless sensor networks (WSN)

*A **Wireless sensor network (WSN)** can be defined as a network of devices, denoted as nodes, which can sense the environment and communicate the information gathered from the monitored field (e.g., an area or volume) through wireless links*

Chiara Buratti, Andrea Conti, Davide Dardari and Roberto Verdone 2009 ISSN 1424-8220

Libelium Smart World



Air Pollution
Control of CO_2 emissions of factories, pollution emitted by cars and toxic gases generated in farms.

Forest Fire Detection
Monitoring of combustion gases and preemptive fire conditions to define alert zones.

Wine Quality Enhancing
Monitoring soil moisture and trunk diameter in vineyards to control the amount of sugar in grapes and grapevine health.

Offspring Care
Control of growing conditions of the offspring in animal farms to ensure its survival and health.

Sportsmen Care
Vital signs monitoring in high performance centers and fields.

Structural Health
Monitoring of vibrations and material conditions in buildings, bridges and historical monuments.

Quality of Shipment Conditions
Monitoring of vibrations, strokes, container openings or cold chain maintenance for insurance purposes.

Smartphones Detection
Detect iPhone and Android devices and in general any device which works with Wifi or Bluetooth interfaces.

Perimeter Access Control
Access control to restricted areas and detection of people in non-authorized areas.

Radiation Levels
Distributed measurement of radiation levels in nuclear power stations surroundings to generate leakage alerts.

Electromagnetic Levels
Measurement of the energy radiated by cell stations and WiFi routers.

Traffic Congestion
Monitoring of vehicles and pedestrian affluence to optimize driving and walking routes.

Water Quality
Study of water suitability in rivers and the sea for fauna and eligibility for drinkable use.

Golf Courses
Selective irrigation in dry zones to reduce the water resources required in the green.

Waste Management
Detection of rubbish levels in containers to optimize the trash collection routes.

Smart Parking
Monitoring of parking spaces availability in the city.

Smart Roads
Warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.

Smart Lighting
Intelligent and weather adaptive lighting in street lights.

Intelligent Shopping
Getting advices in the point of sale according to customer habits, preferences, presence of allergic components for them or expiring dates.

Noise Urban Maps
Sound monitoring in bar areas and centric zones in real time.

Water Leakages
Detection of liquid presence outside tanks and pressure variations along pipes.

Vehicle Auto-diagnosis
Information collection from CanBus to send real time alarms to emergencies or provide advice to drivers.

Item Location
Search of individual items in big surfaces like warehouses or harbours.

libelium
www.libelium.com

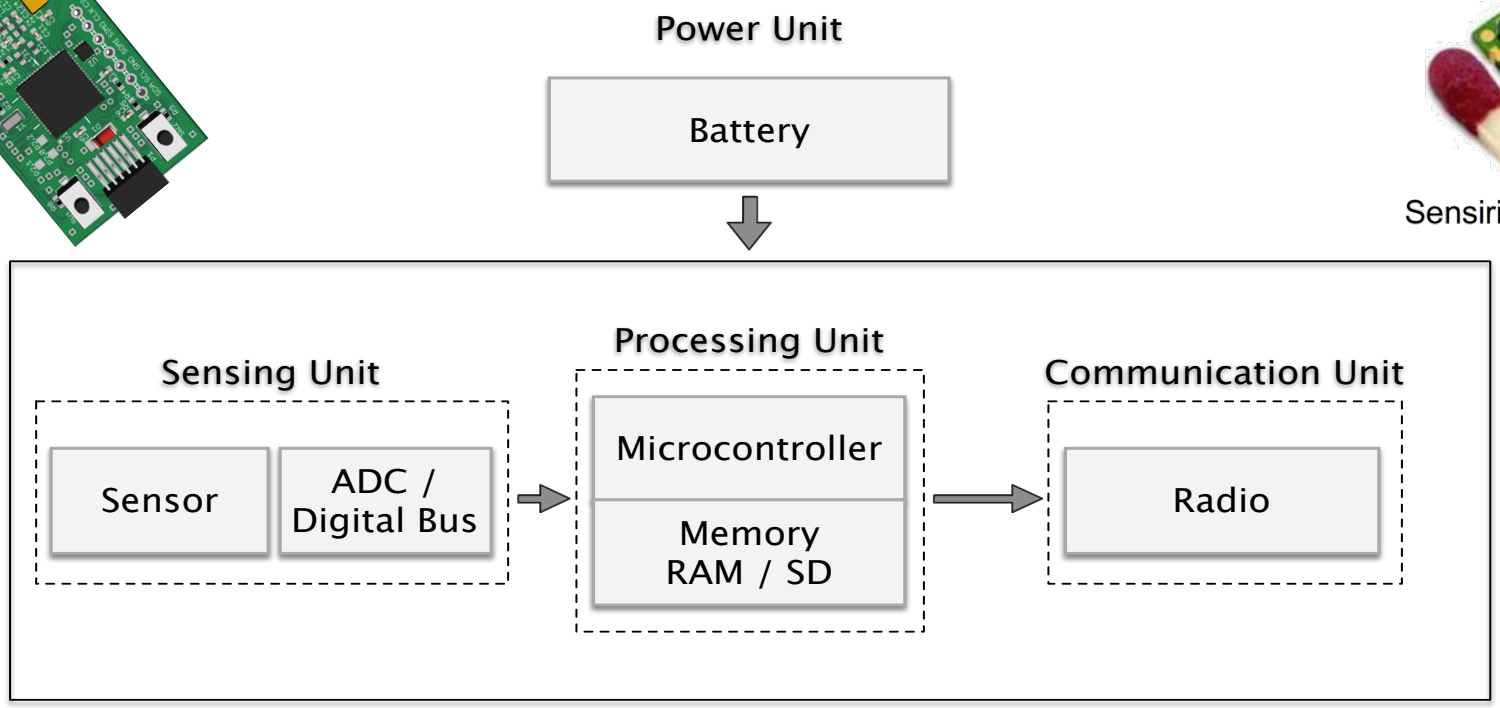
http://www.libelium.com/wp-content/themes/libelium/images/content/applications/libelium_smart_world_infographic_big.png

Applications

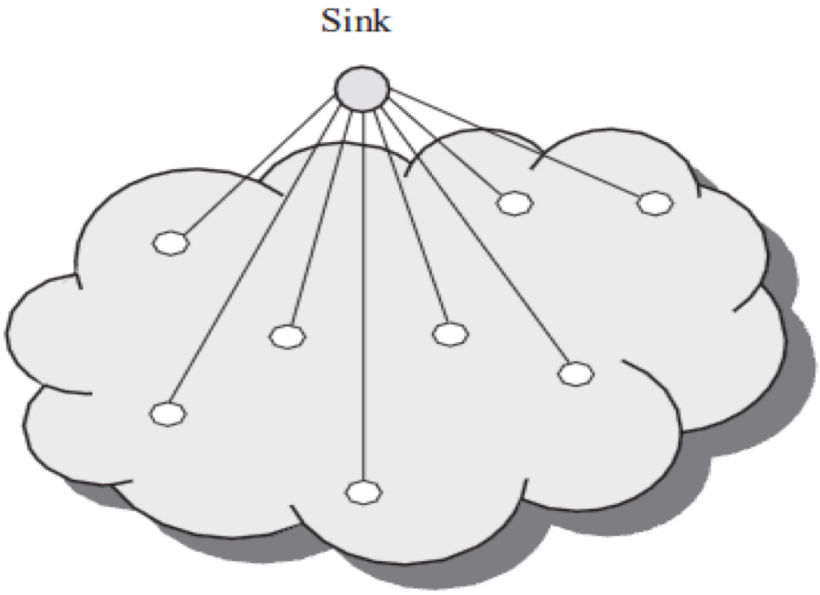
- Environment
  - Air and water quality
  - Sea temperature
  - Eruption monitoring
- Health Care
  - Blood glucose
  - Heart rate
- Commercial use
  - Customer tracking
  - Advertisement
- Home Intelligence
  - Smart Home
  - Light sensor / switch (WSAN)
- Military

Sensor Module / Node

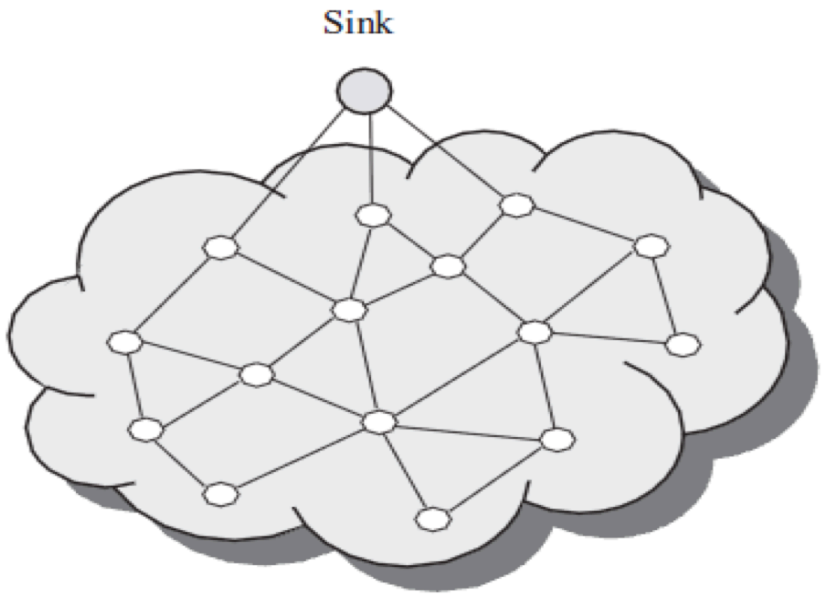
Sensirion SHT11



Network



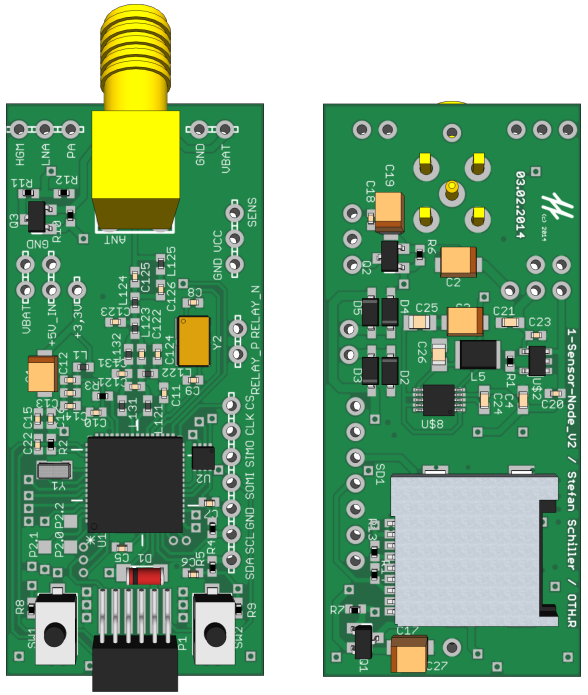
Single-hop network



Multi-hop network

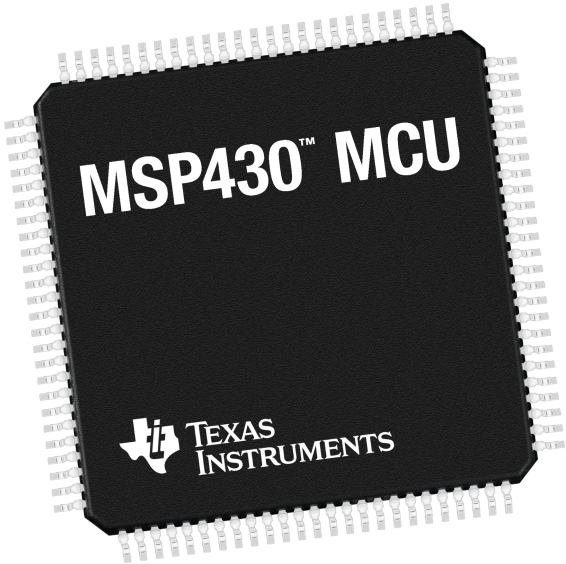
CC430 target board

- CC430F6137
- microSD card
- UART
- SPI
- push button



CC430F6137

- 16 bit Microcontroller
- 20 MHz maximal frequency
- 32 kB of Flash memory
- 4 kB RAM
- 44 GPIO
- 2x 16 bit Timers
- 10 and 12 bit ADC
- 128 Bit AES Security Encryption Coprocessor
- Communication via UART, SPI and I^2C



Integrated CC1101

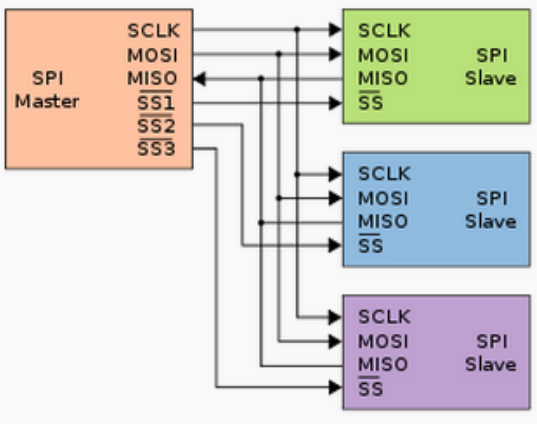
- sub 1 GHz Transceiver
- 300 – 928 MHz Freqency band
- Programmable data rate from 0.6 to 600 kbps
- Low power consumption (14.7 mA in RX mode)
- High Sensitivity

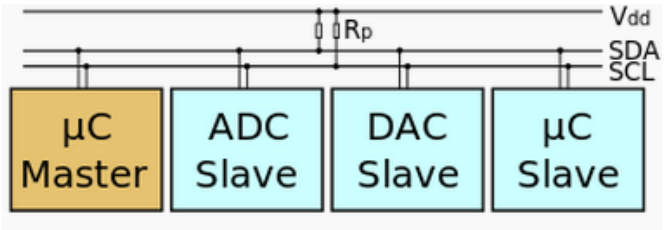
Low Power Modes

- **Active mode:**
- **LPM0**: SMCLK and ACLK active. CPU and MCLK disabled
- **LPM1**: ACLK is active. CPU, MCLK are disabled. SMCLK depend
- **LPM2**: DC generator and ACLK active.
  CPU, MCLK, SMCLK, DCO are disabled
- **LPM3**: ACLK active. CPU, MCLK and SMCLK disabled
- **LPM4**: CPU and all clocks disabled

SPI and I2C

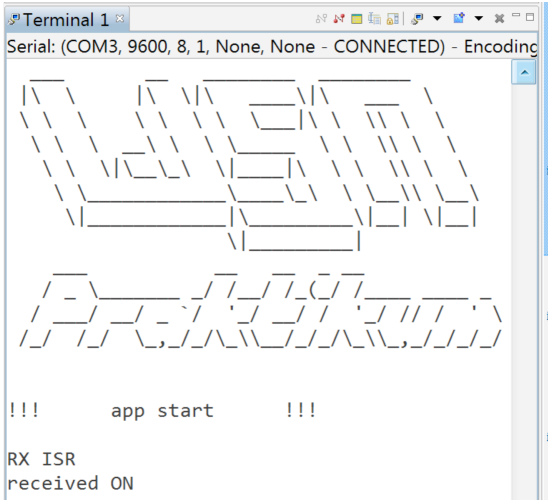
- Universal Serial Communication Interface (USCI)
- Synchronous communication





UART

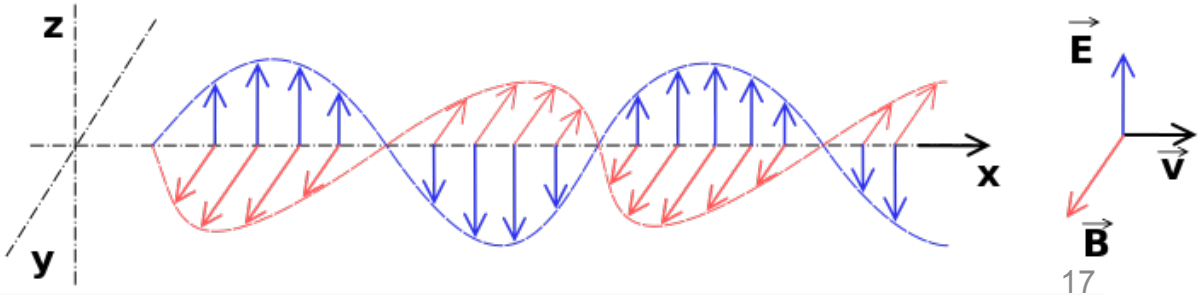
- Universal Asynchronous Receiver Transmitter
- Asynchronous communication



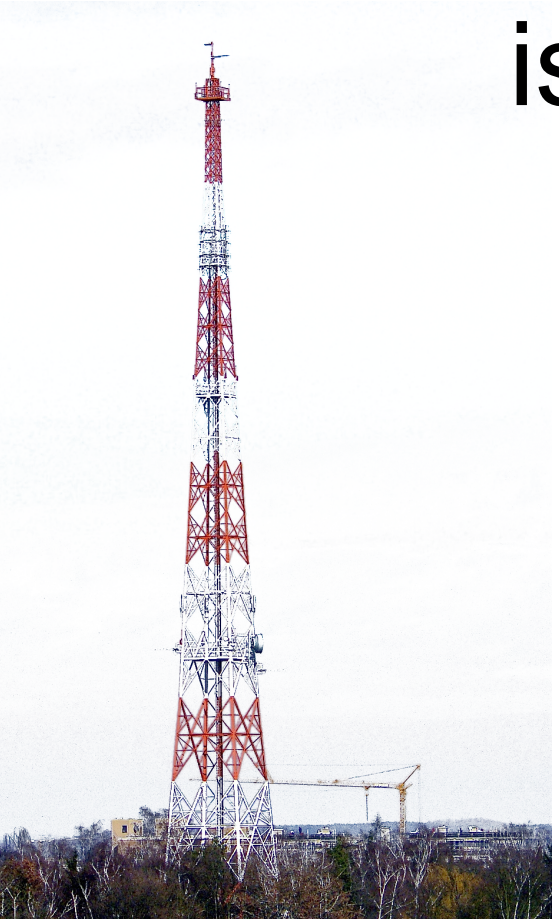
- USB Serial Adapter
- Terminal program

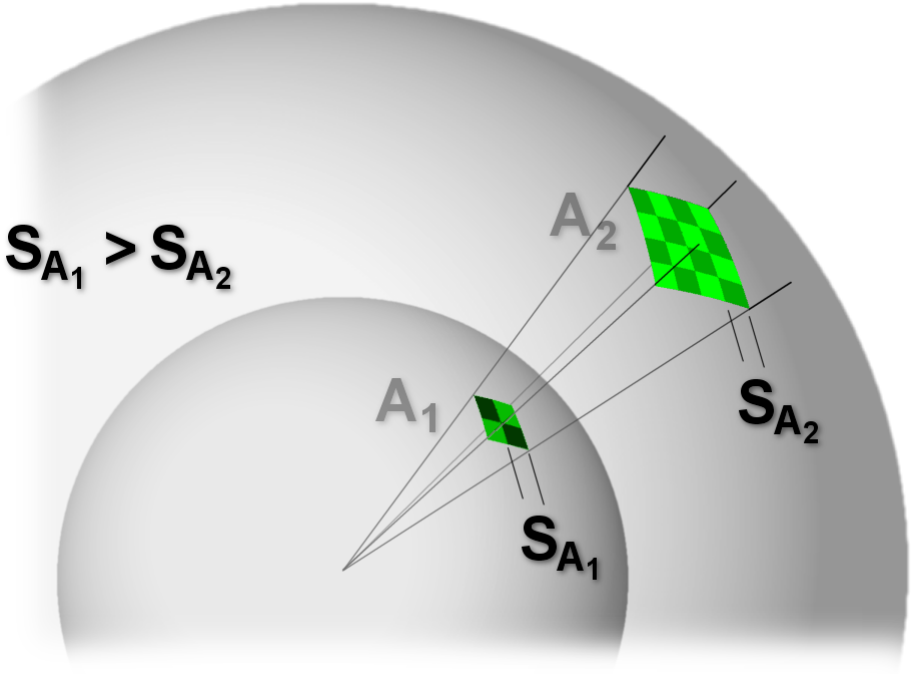
Wireless data transmission

Data transmission via electromagnetic radioation



isotropic radiator



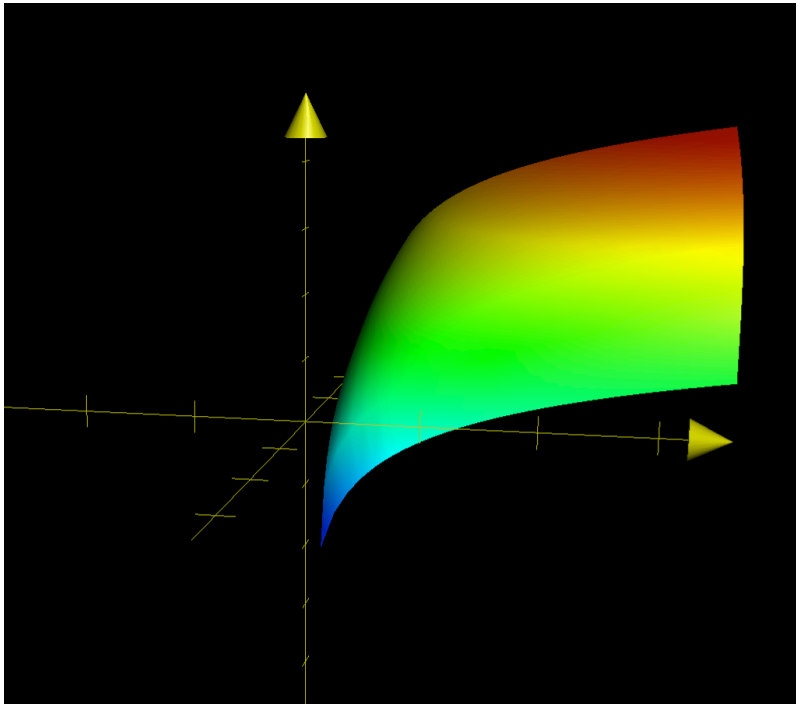


Free-space path loss

$$FSPL(dB) = 10 \log_{10}\left(\frac{4\pi r \cdot f}{c}\right)^2$$

$$= 20 \log_{10}(r) + 20 \log_{10}(f) + 20 \log_{10}\left(\frac{4\,\pi}{c}\right)$$

$$= 20 \log_{10}(r) + 20 \log_{10}(f) - 147{,}55$$

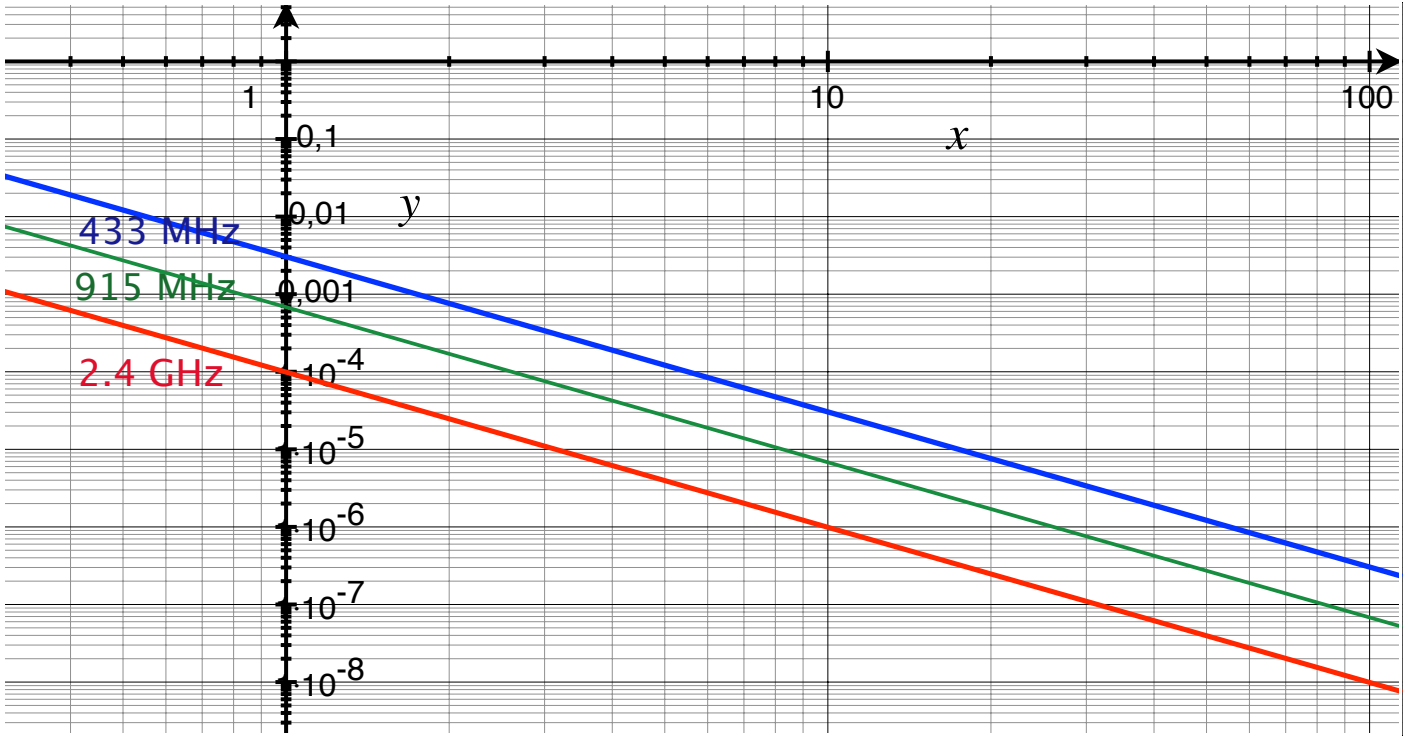


Received energy

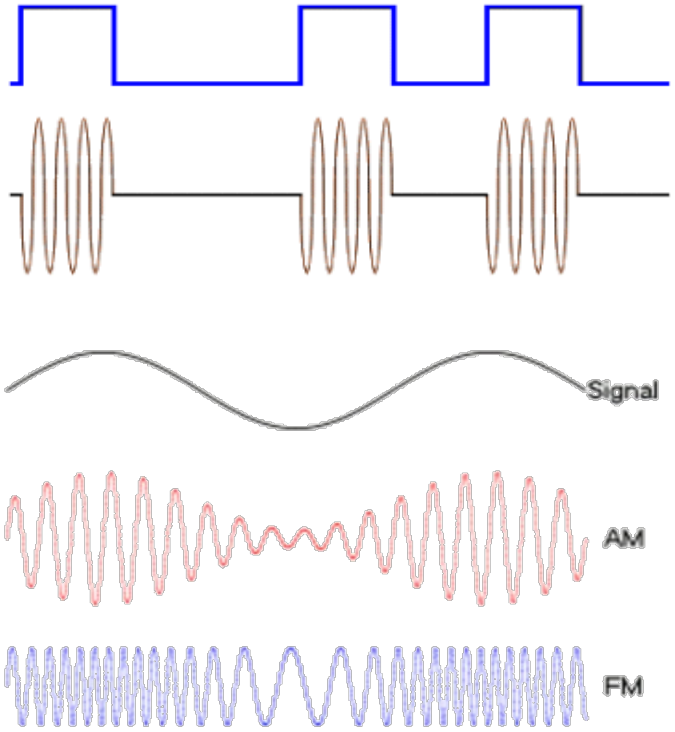
$$P_r = \frac{P}{4\pi r^2} \cdot \frac{\lambda^2}{4\pi}$$

$$= P \cdot \left(\frac{\lambda}{4\pi r}\right)^2$$

$$\lambda = \frac{c}{f}$$



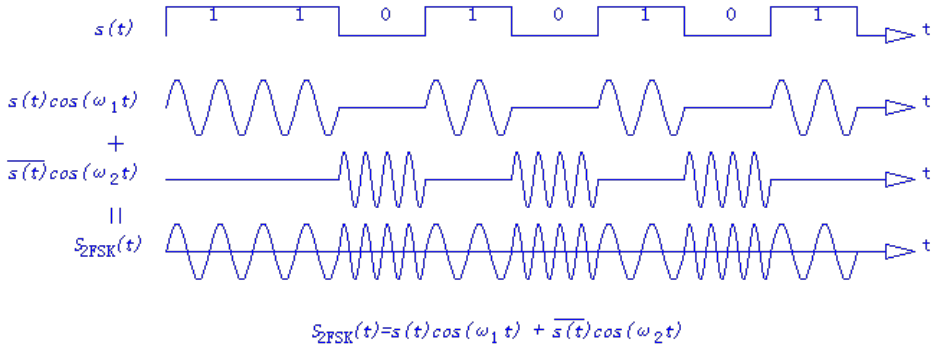
Signal modulation



OOK : On Off keying

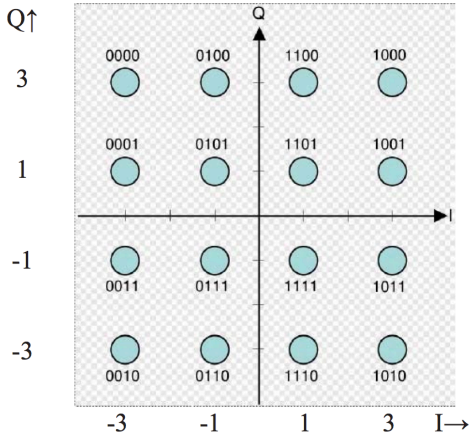
AM: Amplitude modulation

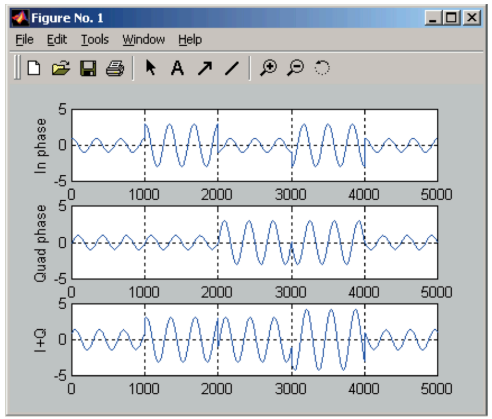
FM: Frequency modulation



2-FSK: Frequency Shift keying

4-FSK, GFSK





MSK: Minimum Shift keying

QAM, FSK, ASK

base frequency bands

ISM

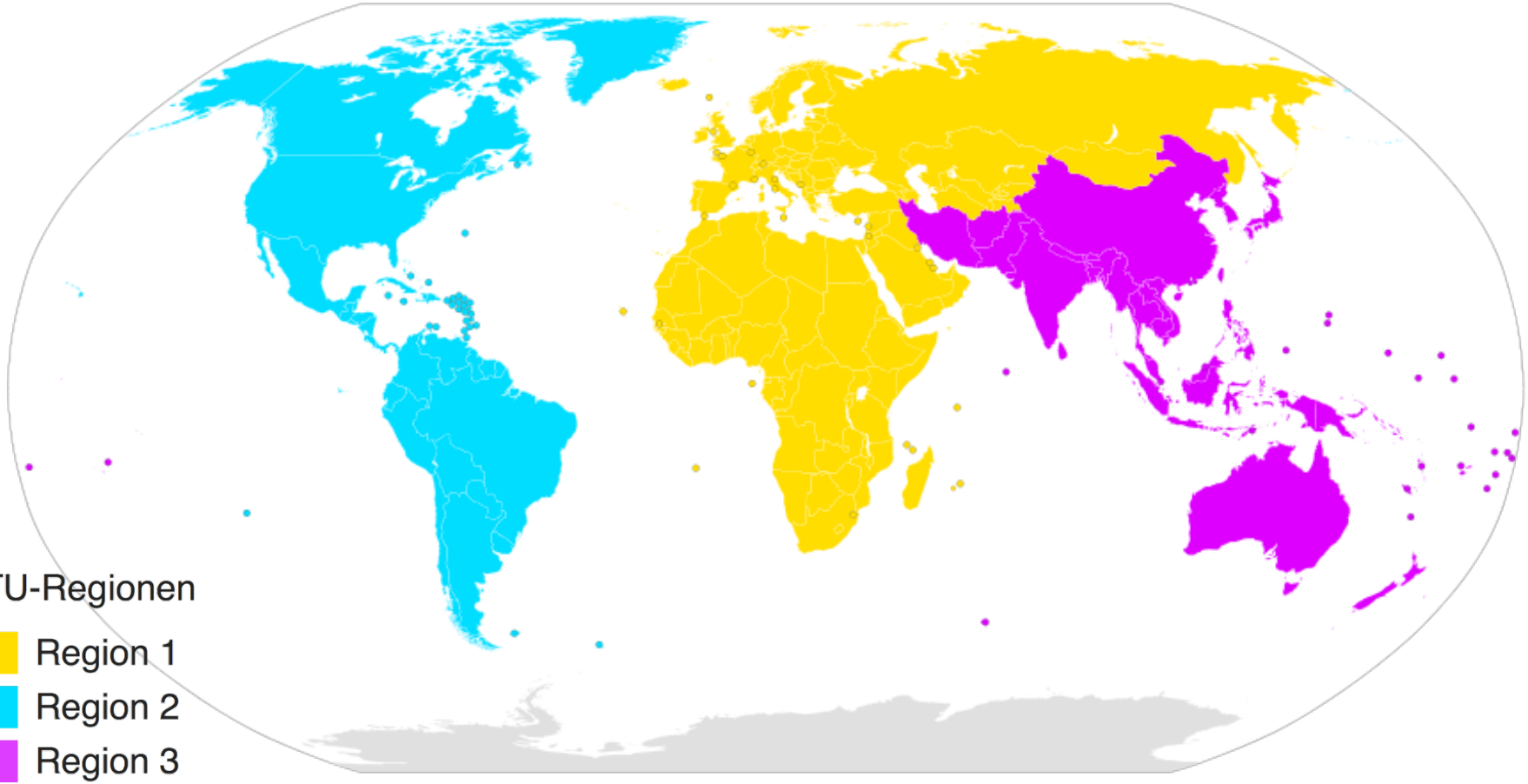
Industrial, Scientific and Medical Band

433 MHz Region 1 (Europa, Africa)
902 MHz Region 2 (America)
2,4 GHz

SRD

Short Range Devices

433 MHz
868 MHz
some ranges at 2,45 GHz
(typically limited to 25-100 mW ERP)

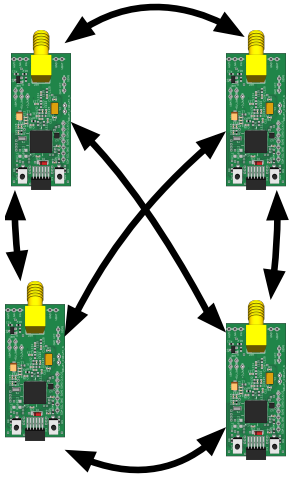

ITU-Regionen
Region 1
Region 2
Region 3

SimpliciTI

RF protocol for MSP430 microcontrollers

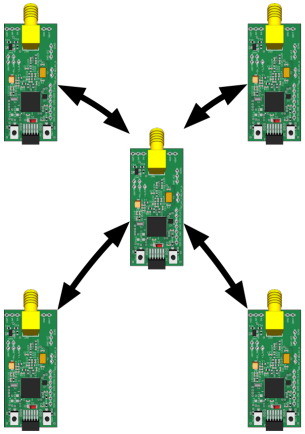
- handling network traffic
- routing/forwarding messages
- data encryption
- CRC
- data whitening

Architecture



Topologies:

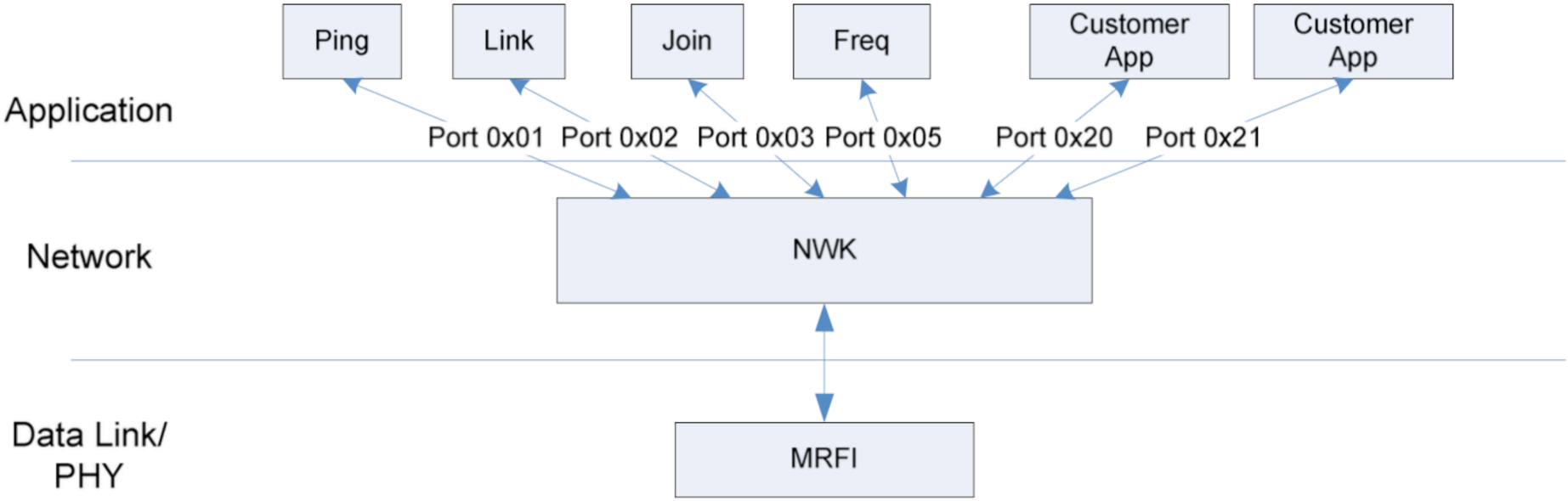
- Peer-to-Peer
- Star Topology



Types of devices:

- Access Point (AP)
- End Device (ED)
- Range Extender (RE)

SimpliciTI Layers vs OSI



OSI Model (7 layers)		Internet Model (4 layers)		
Layer Name		*Layer Name*	*Protocol*	*Address*
Application		**Application**	Telnet, SSH	hostname
Presentation			E-mail	user@domain
Session			Web Browser	URL
Transport		**Transport**	Transmission Control Protocol or User Datagram Protocol	Port Numbers
Network		**Network**	Interrnet Protocol	IP Address
Data Link		**Network Interface**	Network Interface Device FastEthernet, GigE, WiFi (802.11a, b, g, n)	MAC Address
Physical				

http://www.inetdaemon.com/tutorials/basic_concepts/network_models/osi_model/osi_and_internet_protocols.shtml

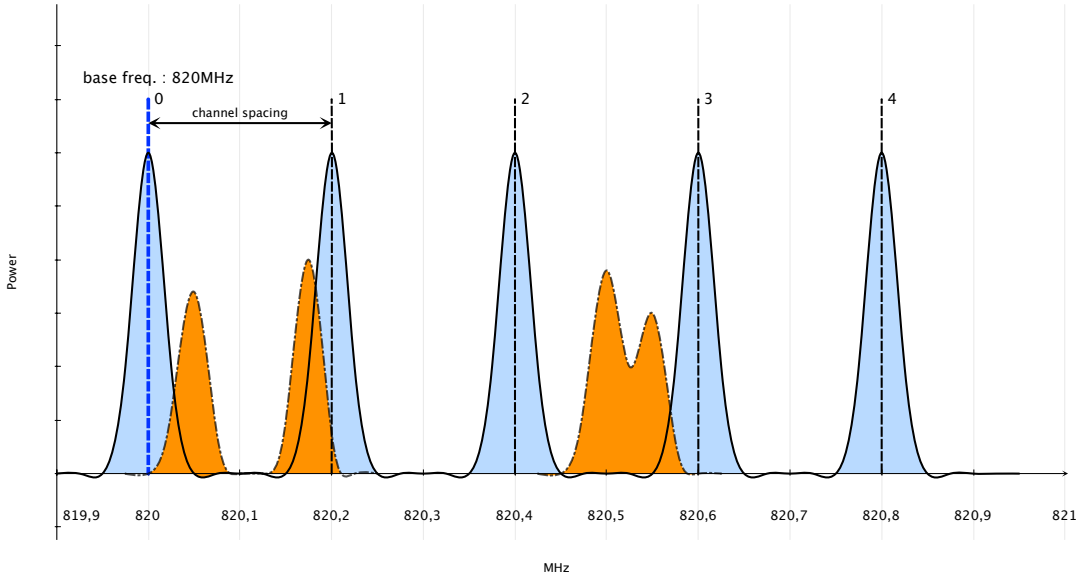
Data Link/Physical layer

- **Board Support Package** (BSP): minimal support to a specific microcontroller
- **Minimal RF Interface** (MRFI): communication with the radio chip

Transmission Frequencies

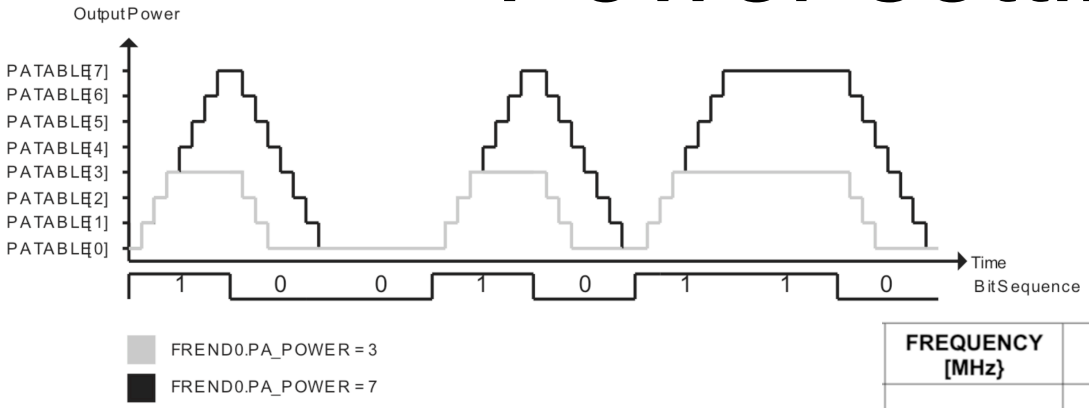
$$f_{carrier} = \frac{f_{XOSC}}{2^{16}} \times \left(FREQ + CHAN \times \left(\left(256 + CHANSPC\_M\right) \times 2^{CHANSPC\_E-2}\right)\right)$$

RF Transmission Frequencies



CC1100/CC1110	
Freq(MHz)	Channel Numbers
902	
904	
906	20
908	
910	
912	50
914	
916	
918	80
920	
922	
924	110
926	
928	

Power settings



$$P(mW) = 10^{\left(\frac{Lp(dBm)}{10}\right)}$$

$$L_p(dBm) = 10\log_{10}\left(\frac{P}{1\,mW}\right)$$

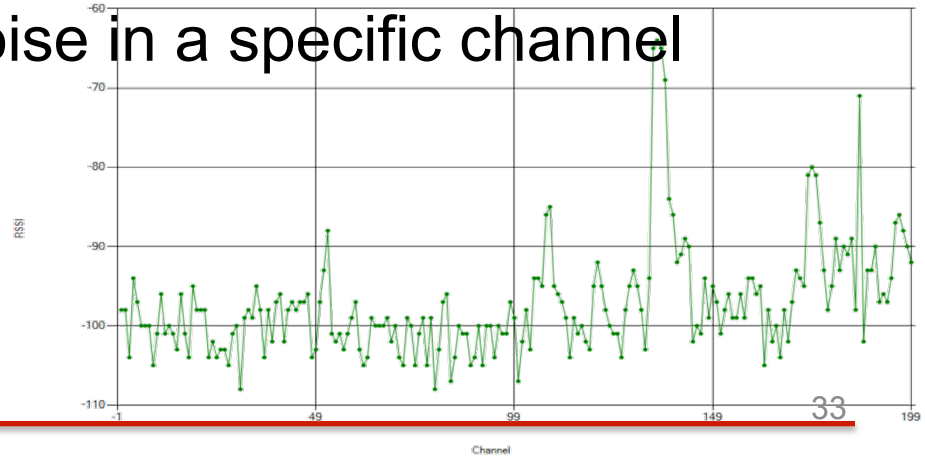
FREQUENCY [MHz]	PATABLE Setting	OUTPUT POWER (dBm)	MIN	TYP	MAX	UNIT
315	0xC0	max.		26		mA
	0xC4	+10		25		mA
	0x51	0		15		mA
	0x29	-6		15		mA
433	0xC0	max.		33		mA
	0xC6	+10		29		mA
	0x50	0		17		mA
	0x2D	-6		17		mA
868	0xC0	max.		36		mA
	0xC3	+10		33		mA
	0x8D	0		18		mA
	0x2D	-6		18		mA

Cyclic Redundancy Check (CRC)

- Detect accidental change of data during transmission
- A short check value gets attached to the message
- The attached value is the remainder of a polynomial division

Received Signal Strength Indicator (RSSI)

- Indicates the power received in a transmission
- The `MRFI_Rssi()` function provides the RSSI value
- Often used to detect the noise in a specific channel



Clear Channel Assessment (CCA)

Algorithm to minimize collisions between radios:

- Check a channel for a very shot time
- Compare the noise in the channel with the noise of a transmission
- If there is no transmission in this channel send the data
- If the channel is occupied then wait for a while and repeat the process

MRFI frame

- `mrfiPacket_t` : is a structure which contains two type definitions
  a) `Packet.frame`: frame of data

Length (1B)	Source (4B)	Destination (4B)	Payload (Length-8 bytes long)

  b) `Packet.rxMetrics`: statistics on the last received packet

RSSI (1B)	CRC (1b)	LQI (7b)

- `void MRFI_RxCompleteISR()`: received packet interrupt

API of Data Link/Physic Layer

- `BSP_INIT(void)`
- `BSP_Delay(uint16_t usec)`
- `BSP_EARLY_INIT(void)`

- `MRFI_Init(void)`
- `MRFI_Transmit(mrfiPacket_t * pPacket, uint8_t txType)`
- `MRFI_Receive(mrfiPacket_t * pPacket)`
- `Mrfi_RxModeOn(void)`
- `MRFI_RxOn(void)`

API of Data Link/Physic Layer

- `Mrfi_RxModeOff(void)`
- `MRFI_RxIdle(void)`
- `MRFI_Sleep(void)`
- `MRFI_WakeUp(void)`
- `int8_t MRFI_Rssi(void)`
- `uint8_t MRFI_RandomByte(void)`
- `Mrfi_DelayUsec(uint16_t howLong)`
- `MRFI_GetRadioState(void)`

NWK Layer

- **NWK**: connecting two different peers and selecting the proper route
- **APP NWK**: manage network as an internal peer to peer object

SimpliciTI frame

PREAMBLE	SYNC	LENGTH	MISC	DSTADDR	SRCADDR	PORT	DEVICE INFO	TRACTID	App Payload	FCS
RD*	RD*	1	RD*	4	4	1	1	1	*n*	RD*

Network header | App payload

MRFI header | MRFI payload

MRFI frame

SimpliciTI frame

PREAMBLE Radio synchronization

SYNC Radio synchronization

LENGTH Length of remaining packet in bytes

MISC Miscellaneous frame fields

DST ADDR Destination address

SRCADDR Source address

PORT Forwarded frame (7), Encryption context (6) Application port number (5

DEVICE INFO Sender/receiver and platform capabilities

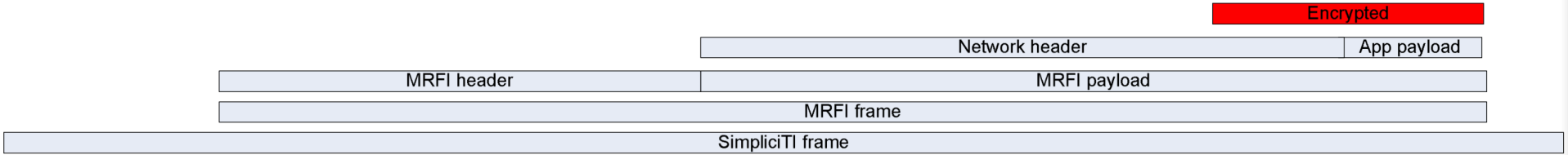
TRACTID Transaction id

APP PAYLOAD Application data

FCS Frame Check Sequence

secure SimpliciTI frame

PREAMBLE	SYNC	LENGTH	MISC	DSTADDR	SRCADDR	PORT	DEVICE INFO	TRACTID	Security		App Payload	FCS
RD*	RD*	1	RD*	4	4	1	1	1	CTR (1)	MAC (2)	*n*	RD*



API of NWK

- SMPL_Init
- SMPL_Link
- SMPL_Unlink
- SMPL_LinkListen
- SMPL_Send
- SMPL_SendOpt
- SMPL_Receive
- SMPL_Ping

API of NWK

SMPL_Ioctl: change configuration parameters while run time

- Frequency
- Radio
- Encryption
- Access to current connection
- Firmware and protocol characteristics
- AP nwk mgmt control