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Implementando uma rede sem fio com Redes Mesh

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Objetivos da Aula

Depois de completar essa aula você será capaz de compreender:

- **Os tipos de Redes Sem Fio**
- **As características de redes mesh em IEEE 802.15.4**
- **As características do Protocolo MiWi**
- **As ferramentas de análise de rede**
- **O desenvolvimento de uma rede mesh de sensores sem fio para iluminação**

Agenda

- Redes Sem Fio
- Fundamentos do IEEE 802.15.4
- Microchip MiWi™
- Ferramentas de Análise de Rede
- Lab: Sistema mesh em iluminação
- Sumário
- Perguntas & Respostas

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Redes Sem Fio

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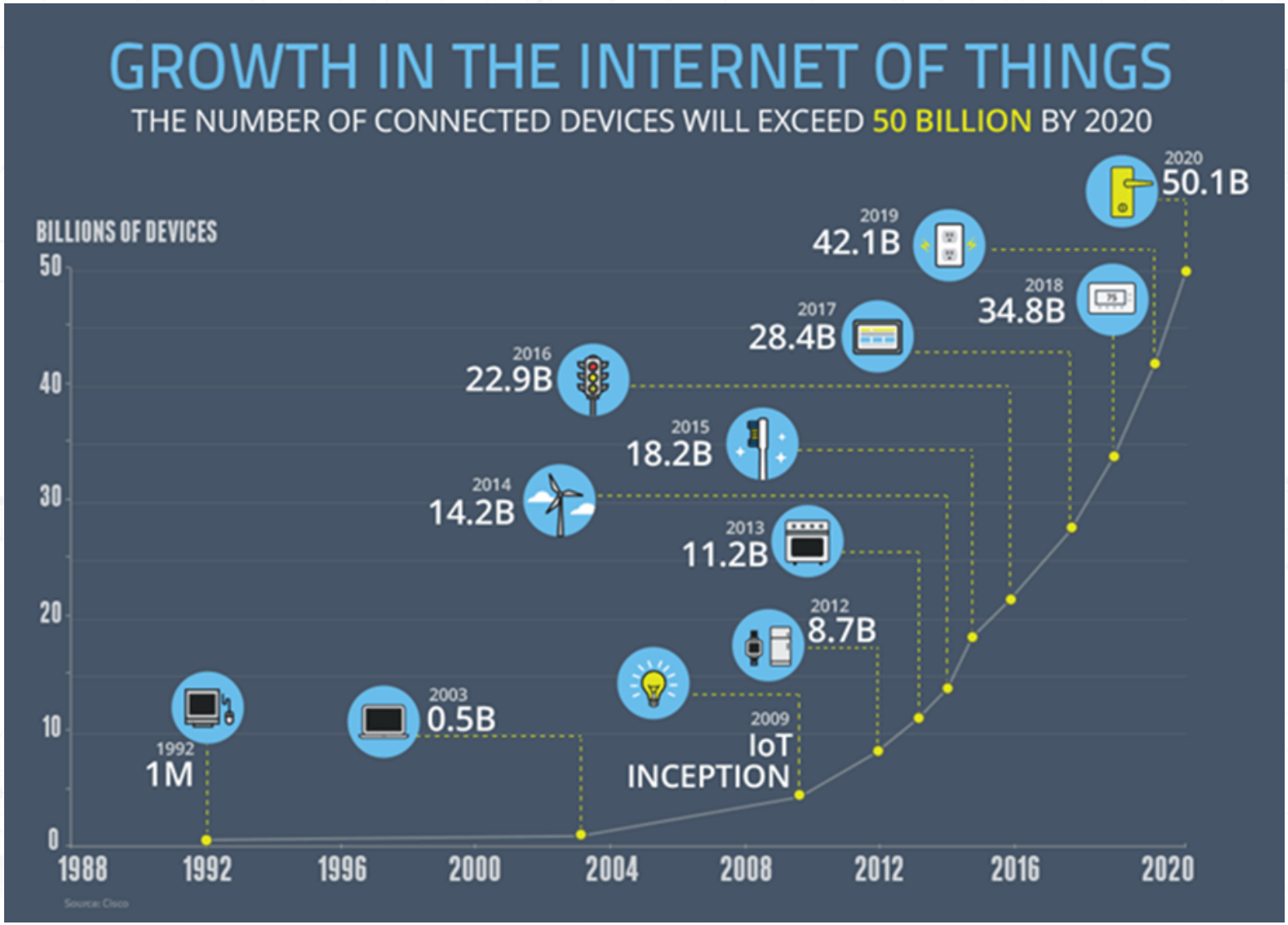
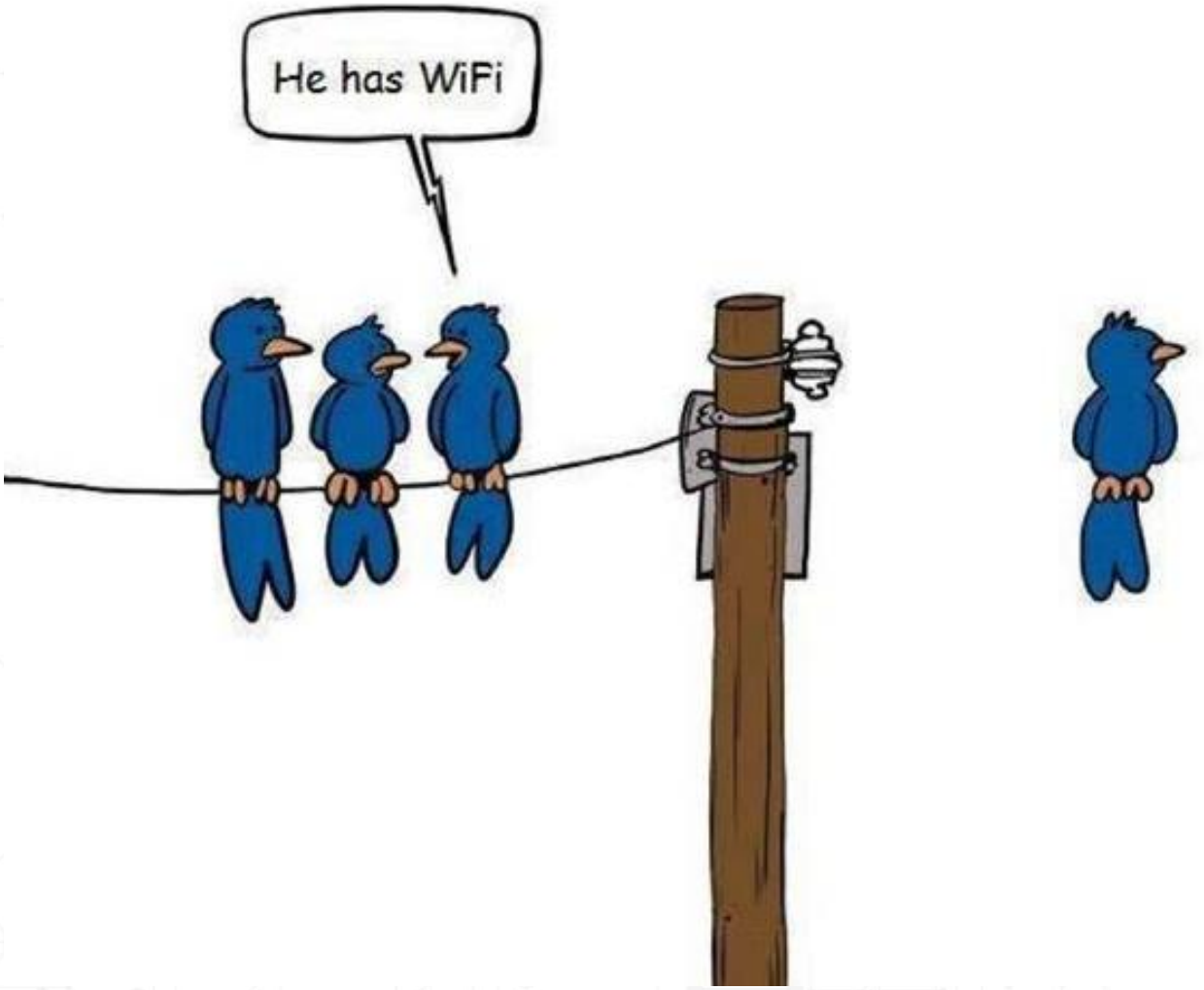
Crescimento de IoT



Smart Egg

A vida sem fios...



Mas em qual padrão?

Guia de Seleção Rede Sem Fio

Range

20m
100m

100m

100m

200m

30km

Data Rate

100-600bit/s

250Kb/s

250Kb/s

<1Mb/s

72Mb/s

Battery Life

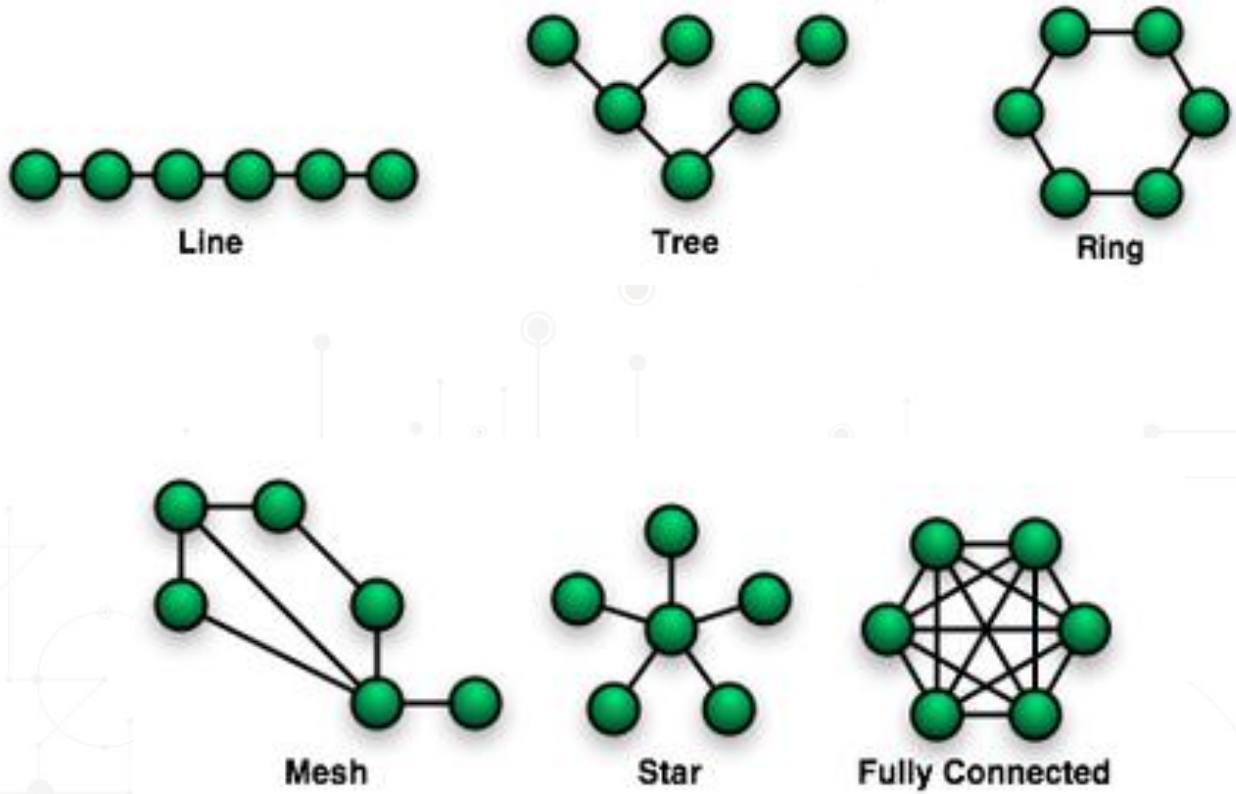
Longer ⟷ Shorter

Directly Connect with a Mobile Device

Direct Internet/Cloud Connection

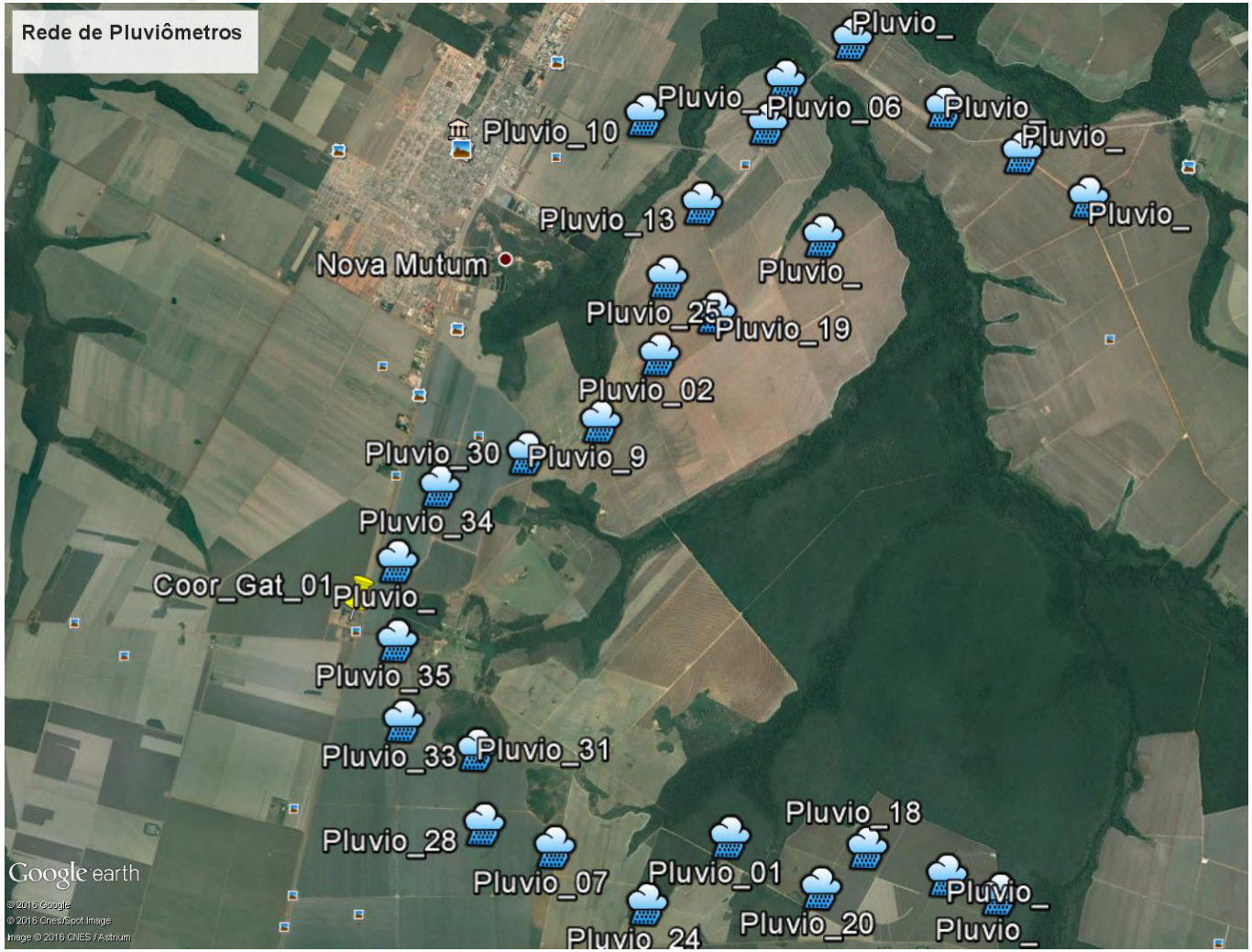
Gateway Needed for Internet/Cloud Connection

Topologias de Redes de Sensores Sem Fio



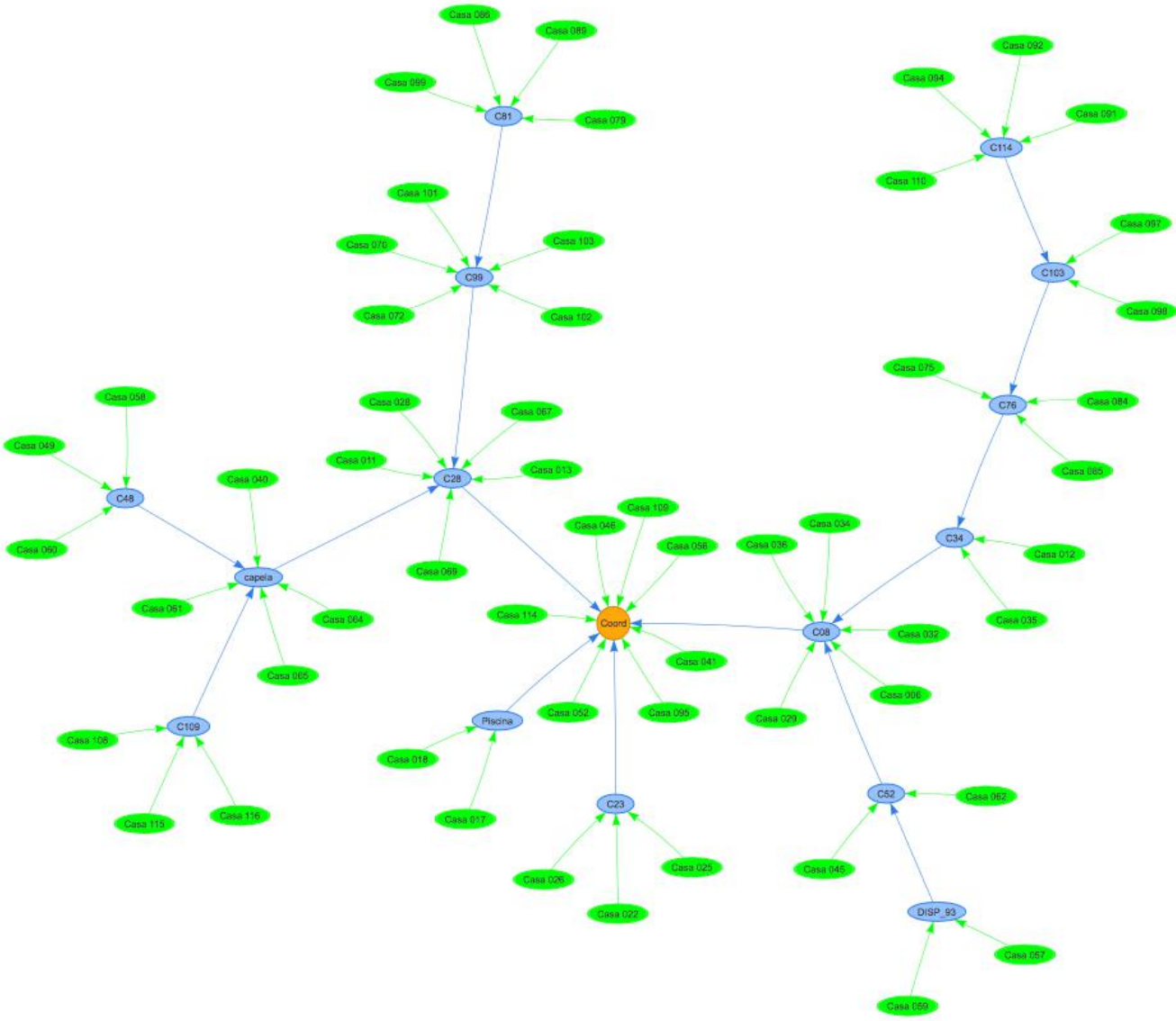
Rede Mesh em Linha

- **Pluviômetros**
- **Distância**
  - 3 km
  - front end 22 dBm
- **Bateria**
  - 3,6V (1 ano)
- **Sem painel solar**
- **802.15.4**
- **Lightweight Mesh**
- **Prevenção Ferrugem da Soja**



Rede Mesh Cluster Tree

- **Utilidades (água, energia e gás)**
- **Distância**
  - 100 m
- **Bateria**
  - 3,6V (5 anos)
- **Roteadores 110/220V**
- **802.15.4**
- **Lightweight Mesh**
- **Eficiência Energética, Hídrica e Identificação de Vazamentos**



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Fundamentos do IEEE 802.15.4

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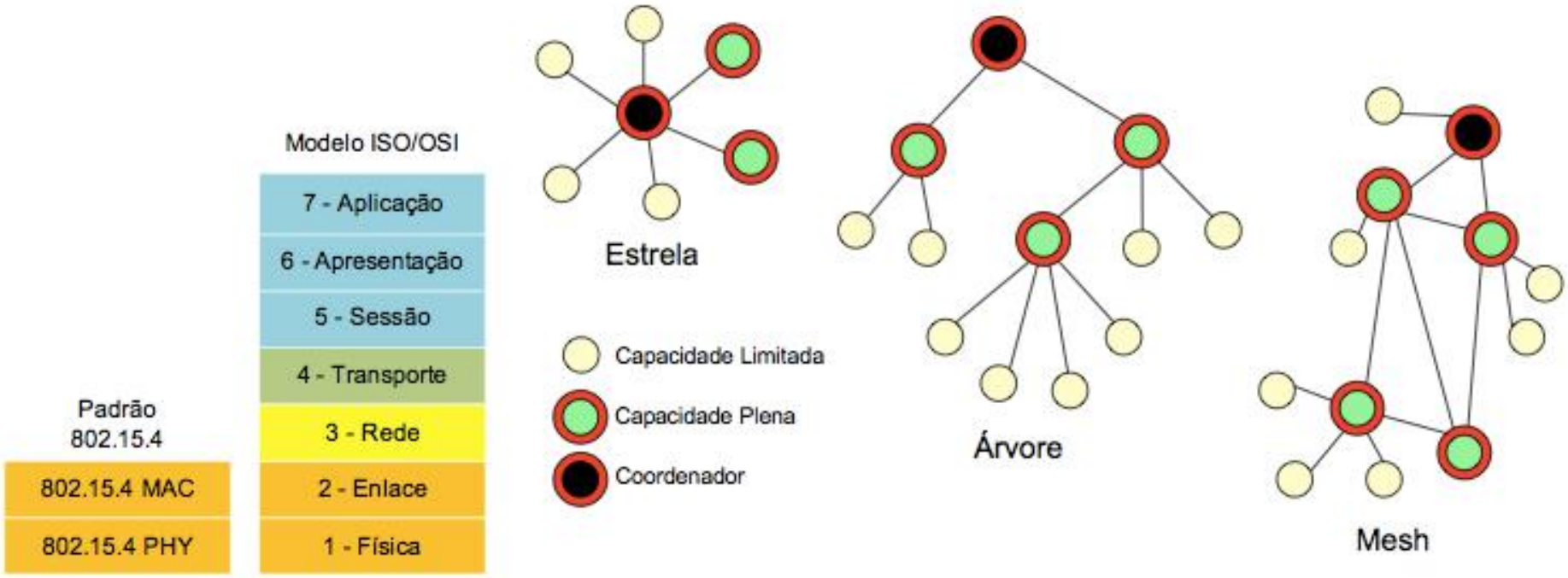
Características IEEE 802.15.4

- **Tipos de dispositivo**
  - Full Function Device – FFD
    - Inicia a rede
    - Manipula o Roteamento
    - Gerencia outras funções
  - Reduced Function Device – RFD
    - Operação simples
    - Associação entre FFD
    - Memória mínima

Características IEEE 802.15.4

- Topologias



Características IEEE 802.15.4

- **Tipos de Mensagens**
  - Broadcast: envio de dados para todos os nós da rede
  - Unicast: envio de dados para um nó exclusivo
- **Segurança**
  - Mensagens encriptadas (CTR ATSAMR21 AES 128 bits)
  - Mensagens autenticadas (CBC-MAC)

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Microchip MiWi™

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Microchip MiWi™

- **Pilha de Protocolo de Rede Sem Fio Proprietária**
- **Suporta**
  - IEEE 802.15.4 – **2.4 GHz**
  - Sub-GHz – **315/433/700/868/915MHz**
- **Projetado para**
  - Taxa de transmissão 250 kbps
  - Distância de 100 metros sem interferência
  - Baixo consumo de energia
- **Topologia de Rede**
  - Peer-2-Peer
  - Star
  - Mesh – 8000 nós – 100 saltos

Características MiWi™

- **Active Scan**
  - Coleta informações de redes PAN próximas
  - Coleta informações de Canal, Potência de Sinal e PAN-ID
- **Energy Scan**
  - Determina o Least Noisy Channel para operação da rede PAN
  - Evita conflitos de interferência de canais no Wi-Fi

Características MiWi™

- **Frequency Agility**
  - Salto de canais
  - Resincronização
  - Gerenciado pelo Pan Coordinator
- **Network Freezer**
  - Quando um device é desligado…
  - Restaura os parâmetros de rede após a falta de energia
  - Armazena essas informações num EEPROM externa

Características MiWi™

- **Sleeping End Devices (RFDs)**
  - Coloca o device no modo sleep para economia de energia
- **Indirect Messaging**
  - Messagens são salvas temporaiamente até que o RFD acorde
- **MCU + TRx em Modo Sleep**
  - ~4uA in SAMR21
  - ~700nA in SAMR30
- **Security AES 128**

Aplicações

Security
Lighting
HVAC
Access, Closures

Monitors
Sensors
Control, Automation

Remote Monitors
Remote Meter Reading

Sensor Monitors
Diagnostics
Dispensing

MiWi™
Applications

RF Remotes
"Gameboys"
PC Peripherals
Gaming and Toys

Security
Lighting
Appliance Control, HVAC
Access, Closures

Porque utilizar o MiWi™

Low Power

- Battery Based Applications

Customizable

- Flexibility in choice of features

Development Time

- Easy to use Interface
- Quick Time to Market

Memory

- Minimal Footprint

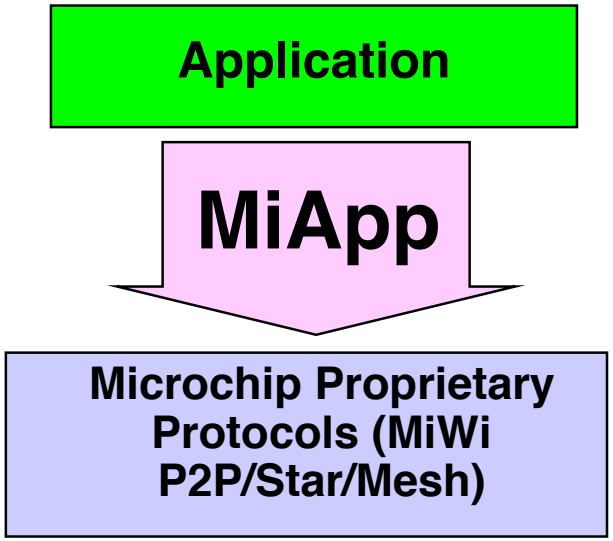
No SW licensing

- Free from Microchip for microchip Designs

Development Platforms

API MiApp

- Abstrai os detalhes da pilha MiWi™
- Quatro categorias de APIs



Configuration

Connection

TX/RX Operation

Special Functions

Aplicação MiApp

```
1  // Configuration
2  MiApp_ProtocolInit(DISABLE_NETFREEZE);
   MiApp_SetChannel(CHANNEL_NUM);

   // Get Connected
3  MiApp_ConnectionMode(ENABLE_ALL_CONN);
4  MiApp_EstablishConnection(CONN_ANY_ADDR, CONN_MODE_DIR);

   // Receive Data
5  if( MiApp_MessageAvailable() )
   {
       LED = RxMessage.PayLoad[DATA_BYTE_X];
6      MiApp_DiscardMessage();
   }

   // Transmit DATA_BYTE to Peer
7  MiApp_FlushTx();
8  MiApp_WriteData(DATA_BUFFER_BYTE_Y);
9  MiApp_UnicastConnection(CONN_INDEX, SECURITY_ENABLE);
```

P2P MiWi™

- **Pros**
  - Simple Network.
  - No Dedicated Pan Coordinator.
  - Secured Connection.
  - Multiple nodes can communicate to each other as long as they are within Radio range
  - Minimal Latency
- **Cons**
  - Short Range.
  - No Hopping.
  - Destination Device must be in the radio range.

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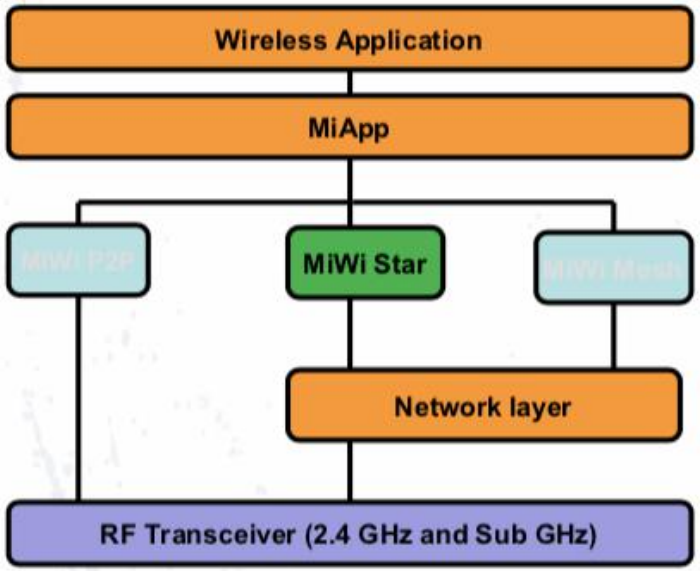
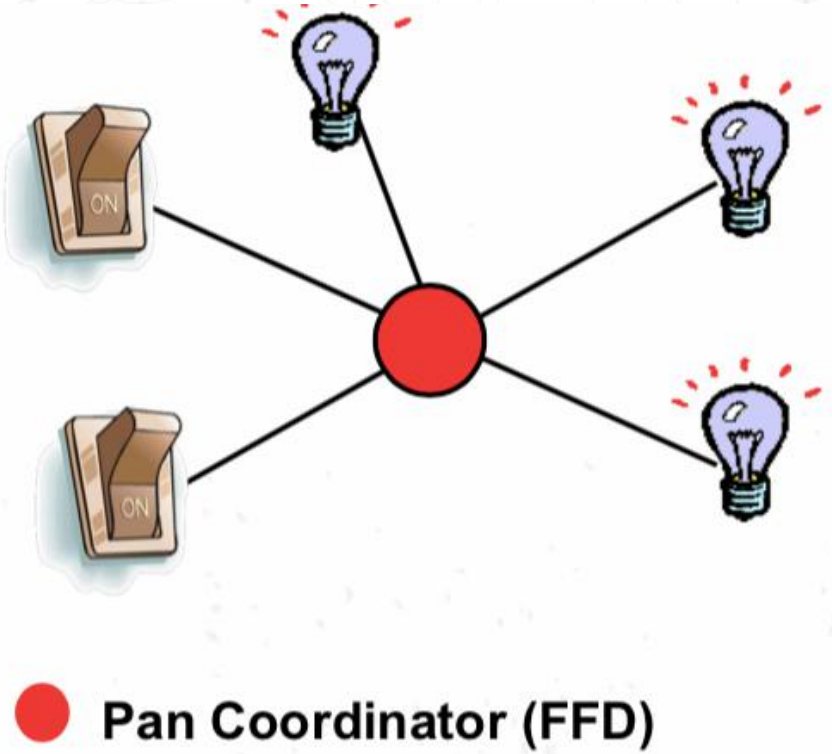
Start MiWi™



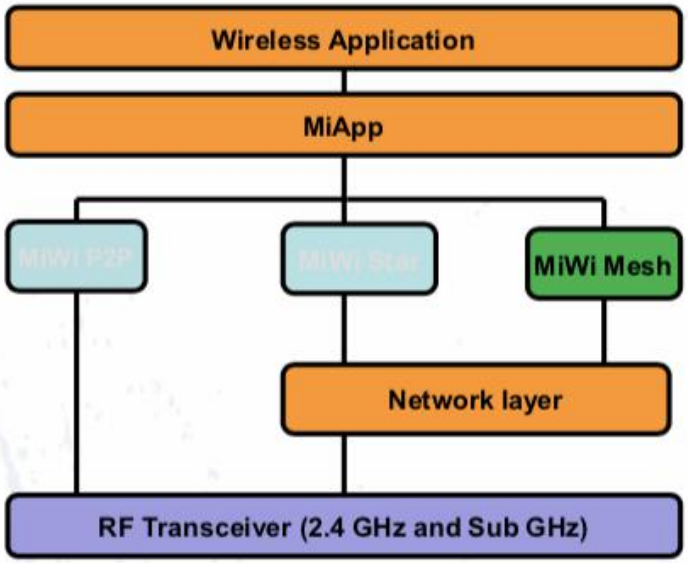


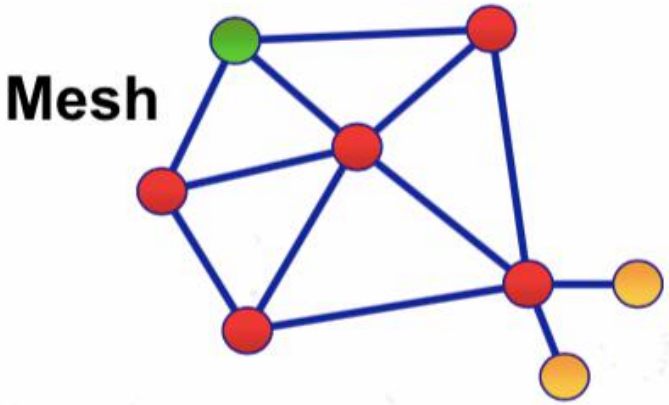
- Supports 2 hops
- Simple and Basic routing
- PAN Coordinator controls network

Start MiWi™

- **Pros**
  - Simple Network.
  - Double the range of P2P.
  - Network Monitoring.
  - Secured Connection.
- **Cons**
  - Larger memory footprint than P2P.
  - Network Failure if Pan Coordinator Fails.
  - Higher Latency.

Mesh MiWi™





PAN Coordinator (FFD)
Coordinator (FFD)
End Device (RFD)

- Supports 100+ hops.

Mesh MiWi™ Tipos de Devices

- **PAN Coordinator**
  - Inicia a rede
  - Associa e mantém os endereços dos Coordenadores e End-Devices
  - Comporta-se como roteador de frames
  - Controla quais devices podem entrar na rede

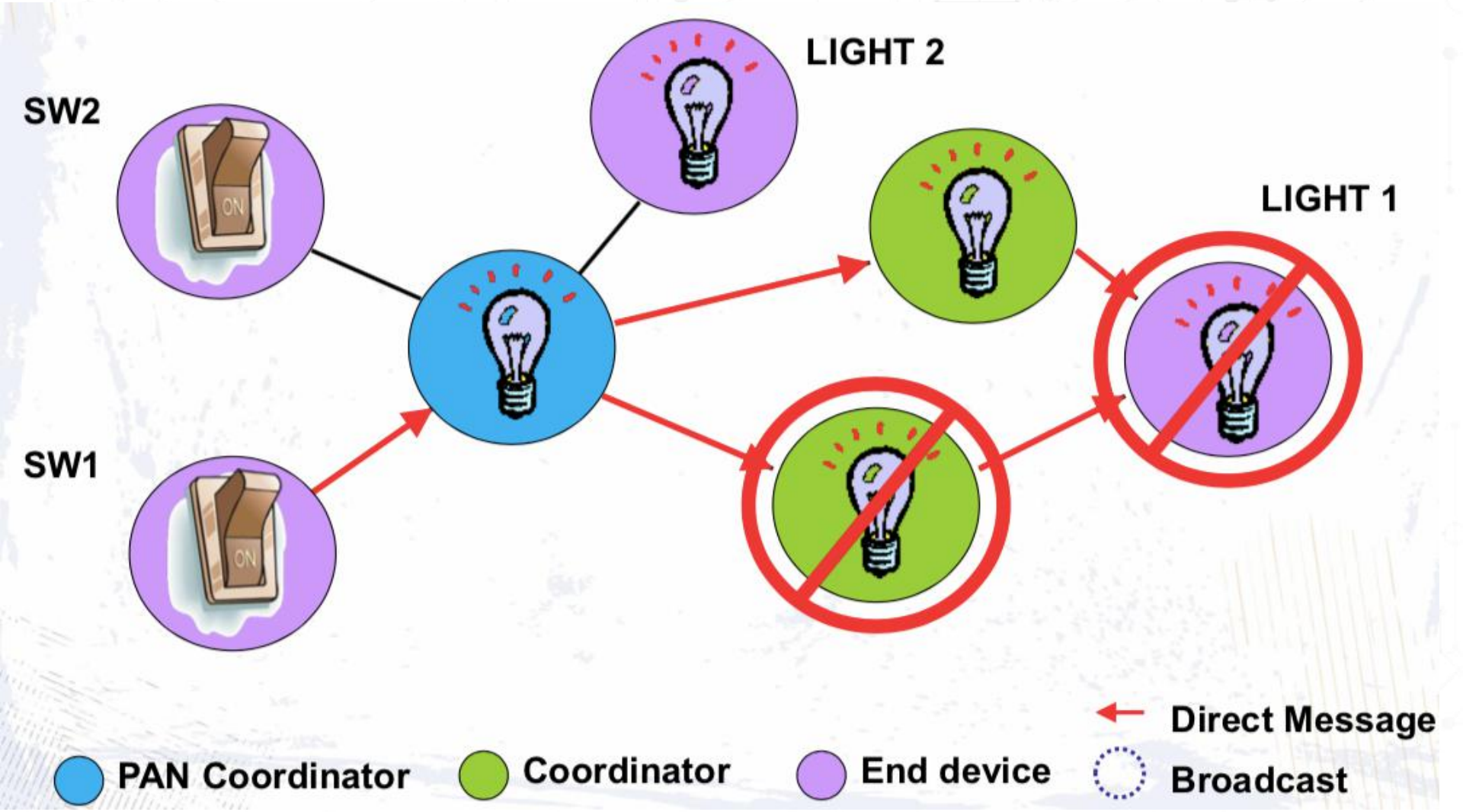
Mesh MiWi™ Tipos de Devices

- **Coordinator**
  - Entra na rede como um End-device
  - Solicita para o PAN Coordinator promoção para Coordinator
  - Comporta-se como roteador de frames
  - Controla quais devices podem entrar na rede através das informações do PAN Coordinator
  - Mantém os End-devices e seus endereços
  - Mantém dados para os end-devices que estão dormindo

Mesh MiWi™ Tipos de Devices

- **End-Device**
  - Entra na rede através dos Coordinators disponíveis
  - Suporta modo Rx-On e modo Sleeping para devices com operação por bateria
  - Suporta troca dinânmica entre os modos Rx-On e Sleeping

Mesh MiWi™



Mesh MiWi™

- **Pros**
  - Extends the range.
  - Switch Device Roles on the Fly.
  - Small Footprint to fit lower memory MCU's.
  - Convenient at locations that do not support wired connections. (Outdoor Concert Venues)
  - Enhanced Commissioning mechanism.
- **Cons**
  - Larger memory footprint than P2P/Star.
  - Higher Latency.

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Ferramentas

- Wireless Performance Analyzer
- Atmel Wireshark Sniffer

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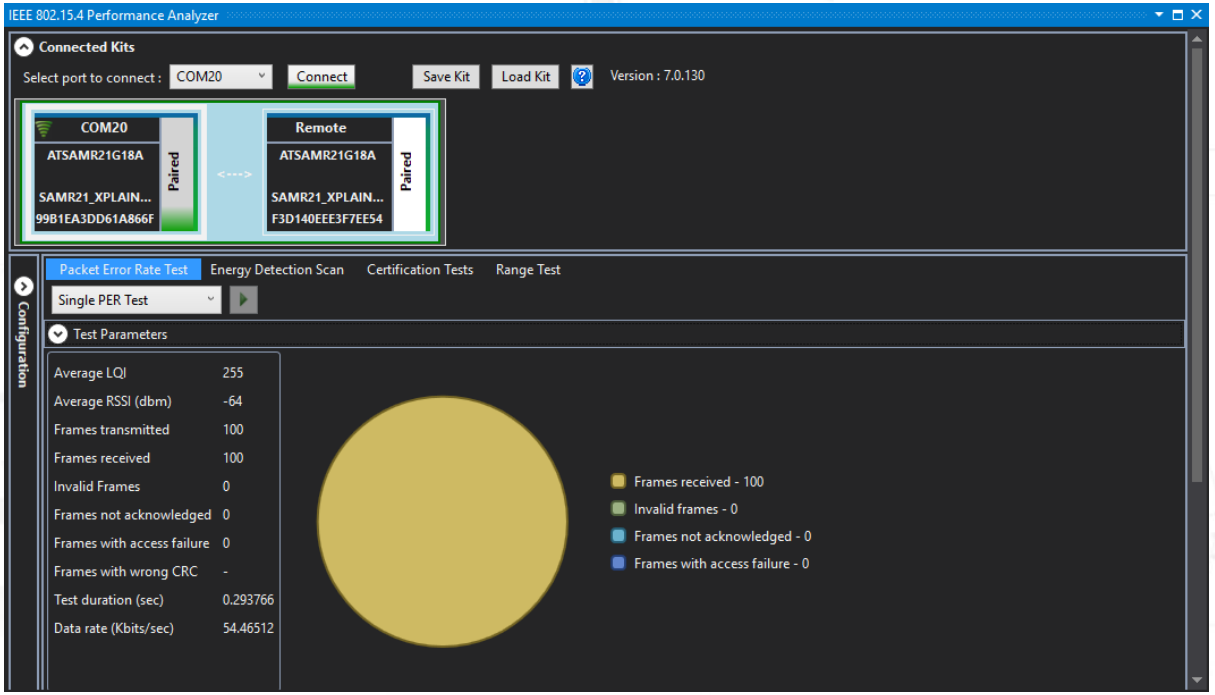
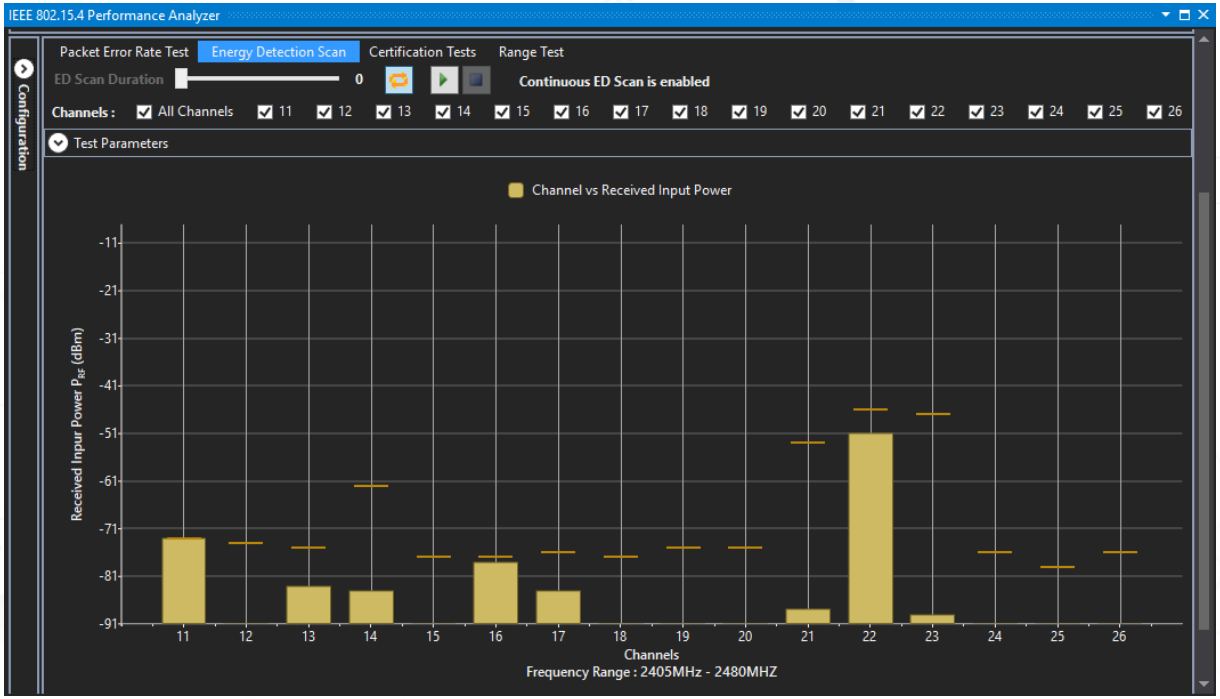
Wireless Performance Analyzer

- Integrada ao Atmel Studio 7
- Funções: teste de taxa de erro de pacotes, transmissão contínua e teste de alcance
- Demonstração



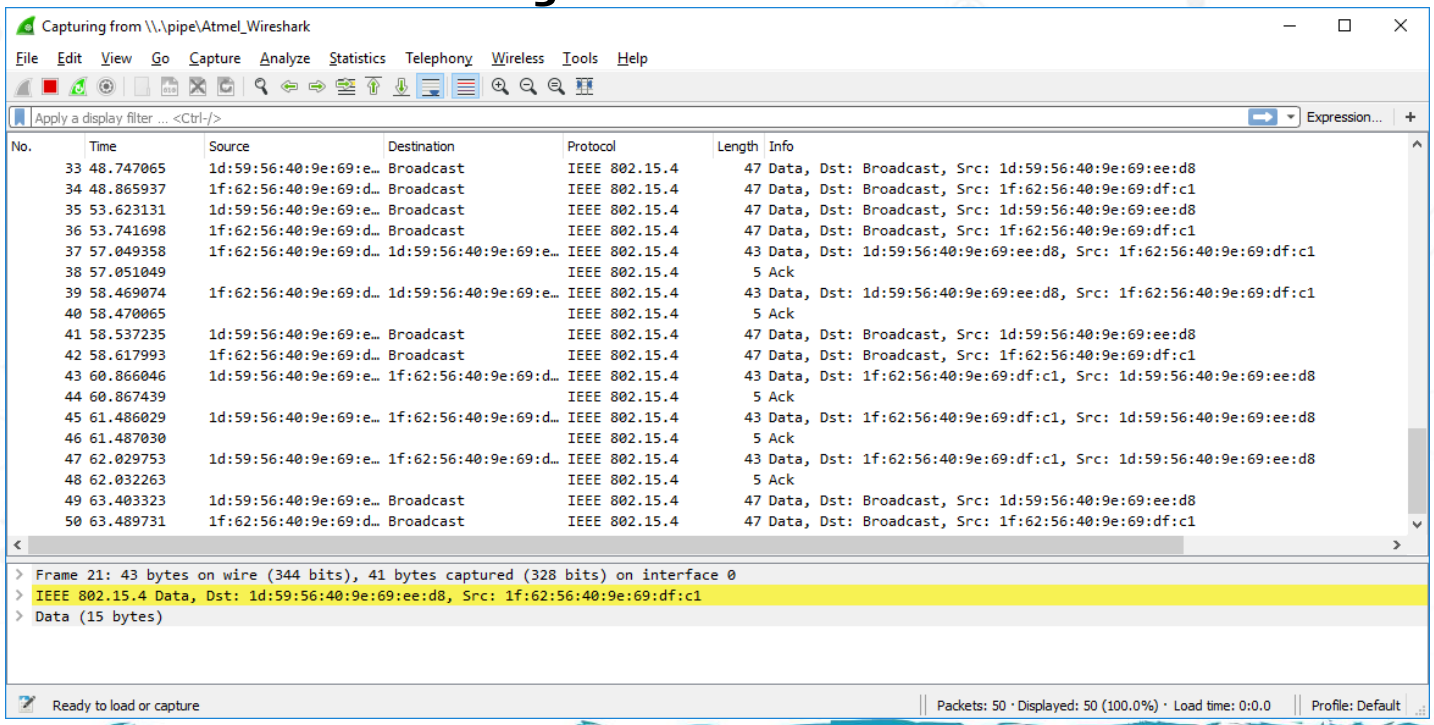
Wireless Performance Analyzer

- Integrada ao Atmel Studio 7
- Funções: detecção de energia por canal
- Demonstração



Atmel Wireshark Sniffer

- Intregrado ao Wireshark Sniffer
- Funções: visualização dos pacotes 802.15.4 trafegando na rede
- Demonstração



ATZB-X-212B-US

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Módulo Mesh Comando AT TecSUS

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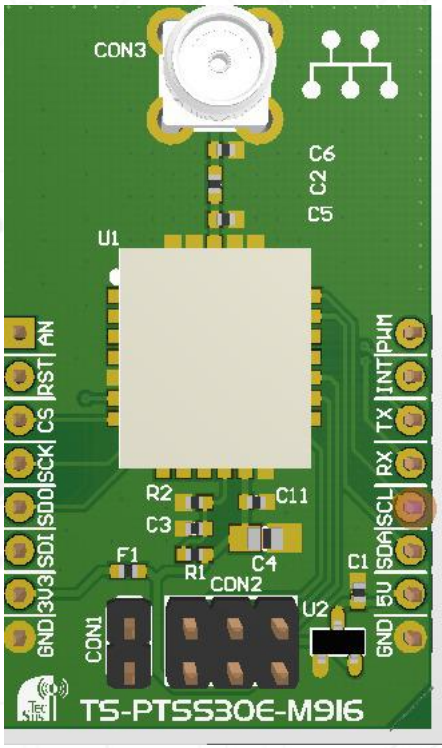
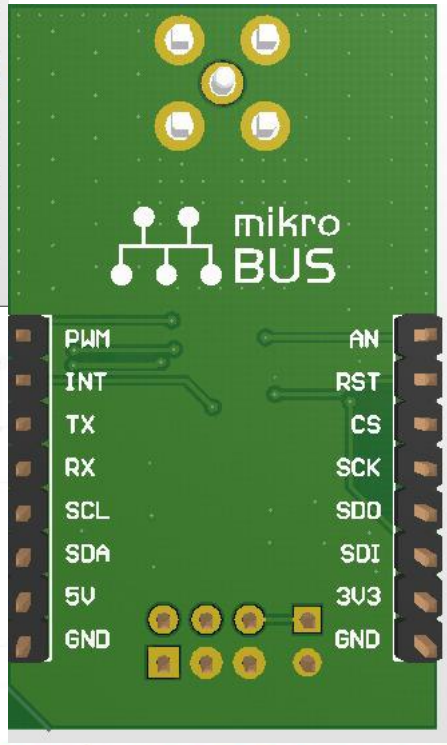
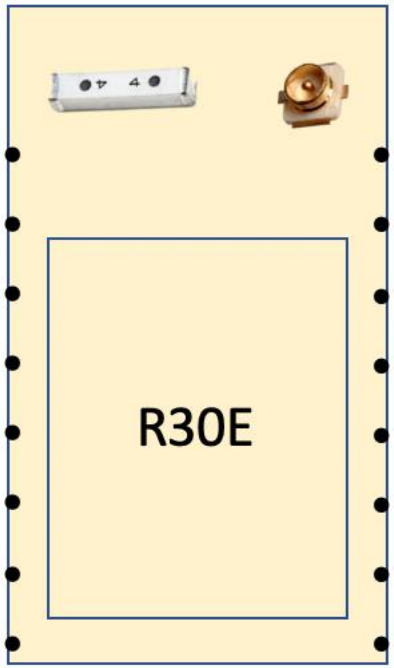
TS-PTSS30E-M916

- **ARM Cortex M0 48MHz**
- **Integrated Ultra-Low Power Transceiver**
  - 900 MHz ISM Band
  - RX sensitivity up to -105 dBm
  - TX output power up to +5dBm
- **Low Power Consumption**
  - Input power: 1.8V – 3.6V
  - Active mode for the microcontroller down to 60µA/MHz
  - Standby mode for the microcontroller down to 4µA/MHz
- **Real-Time Counter**
  - Running at 32 KHz
- **Security & Certification**
  - Crypto Device for ECDSA and ECDH keys
  - AES 128 Bits
  - True Random Generator
- **Serial EEPROM 256/512/1024 Kbit**
  - More than 1 million erase/write cycles
- **Interfaces**
  - 9x GPIO
  - 4x Hardware Interruption
  - 1x UART TTL
  - 1x I2C
  - 1x SPI
  - 1x ADC
  - 1x PWM





TS-PTSS30E-M916



GPIO0 – AN – 1
RST – RESET – 2
GPIO1 – CS – 3
GPIO2 – SCK – 4
GPIO3 – SDO – 5
GPIO4 – SDI – 6
+3.3 – 7
GND – 8

09 – PWM – GPIO5
10 – INT – GPIO6
11 – TX
12 – RX
13 – SCL – GPIO7
14 – SDA – GPIO8
15 – +5V
16 – GND

TS-PTSS30E-M916

- **Comandos AT – 9600 8N1**
  - AT+PANID
  - AT+ADDR
  - AT+CHANNEL
  - AT+CONFGPIO
  - AT+SETGPIO
  - AT+SENDGPIO
  - AT+SENDDATA
  - AT+SAVE
  - AT+REBOOT
  - AT+CURSO

TS-PTSS30E-M916

- **AT+PANID**
  - Configura o “SSID” de rede
  - AT+PAIND=0x1234
- **AT+ADDR**
  - Configura o endereço de rede 0 – PAN Coordinator, 1 – 32768 Coordinator, 32769 – 65534 End Device
  - AT+ADDR=1
- **AT+CHANNEL**
  - Configura o canal de comunicação
  - AT+CHANNEL=6 (916MHz)
- **AT+SAVE**
  - Salva as configurações na memória
  - AT+SAVE

TS-PTSS30E-M916

- **AT+CONFGPIO**
  - Configura os pinos de GPIO (0 – 8) em IN 0 / OUT 1
  - AT+CONFGPIO=6,1 (6-LED)
- **AT+SETGPIO**
  - Muda o estado do pino do GPIO ON 1 / OFF 0
  - AT+SETGPIO=6,1
- **AT+SENDGPIO**
  - Envia um o estado de GPIO para um nó na rede Mesh
  - AT+SENDGPIO=<addr>, <gpio>, <estado>
  - AT+SENDGPIO=15,6,1

TS-PTSS30E-M916

- **AT+SENDDATA**
  - Envia um conjunto de até 64 bytes
  - AT+SENDDATA=ADDR, OLA
- **AT+SAVE**
  - Salva as configurações na memória
  - AT+SAVE
- **AT+REBOOT**
  - Reset do módulo
- **AT+CURSO**
  - Habilita o envio de dados de telemetria simulado (0/1)
  - AT+CURSO=1
- **AT+TRAINING**
  - Habilita no end device o envio de dados simulados ao receber dados
  - AT+TRAINING=1

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Lab: Sistema Mesh em Iluminação

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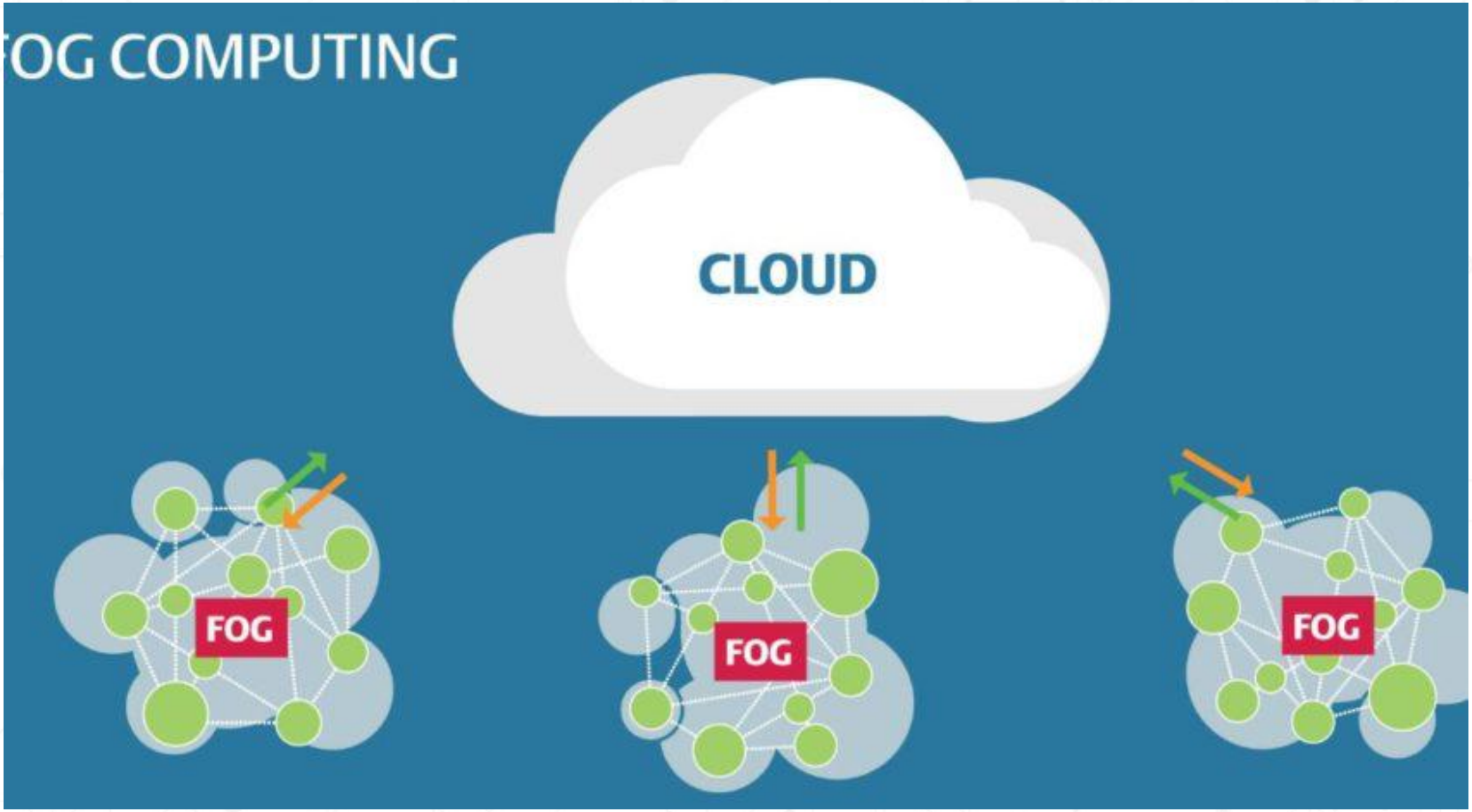
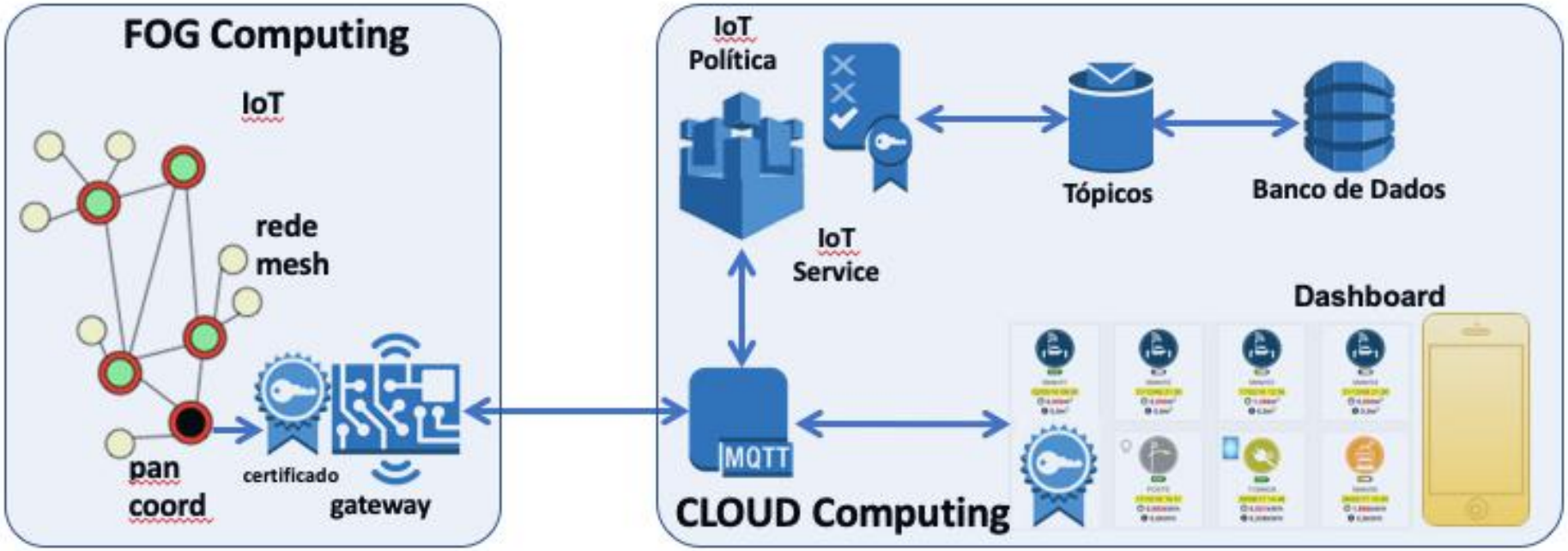
Cloud e Fog Computing

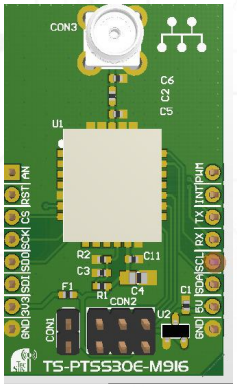


Arquitetura da IoT Street Light

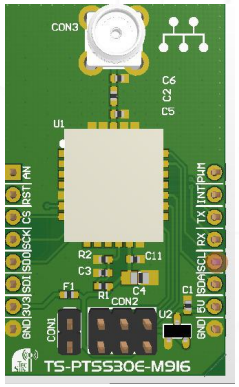


gateway

pan
coord



coord

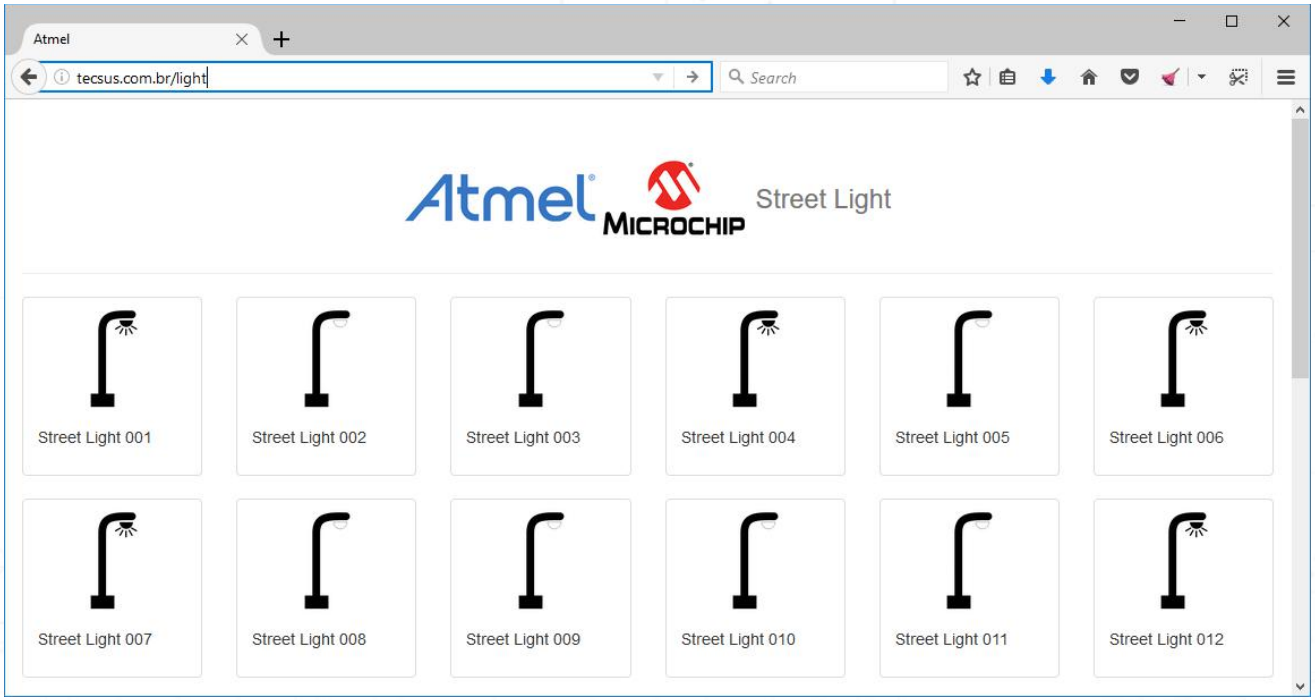


Arquitetura da IoT Street Light

- O Módulo TS-PTSS30E-M916 representa um nó da rede
  - Recebe comando (on/off) da lâmpada (LED)
  - Envia dados de telemetria (temperatura e umidade)
- O gateway será um notebook+TS-PTSS30E-M916
  - Executando código em Python + MQTT
- Gateway mapeará os tópicos para os nó da rede via PANCoordinator
  - Tópico streetlight/cmd/UID/{light: on, temp: 23, hum:25}
  - UID Identificador único do Device

Monitoramento e Controle

- **Painel de Controle via MQTT no Browser**



Configuração

- Repositório de fontes
  - https://github.com/tecsusbr/ucs-microchipday2020
  - https://github.com/tecsusbr/TS-PTSS30E-M916
  - Dashboard
  - Gateway

- Configuração do Módulo por Comando AT
  - 9600
  - 8
  - N
  - 1

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Sumário

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Comparação dos Protocolos

	MiWi™ P2P	MiWi™ Star	MiWi™ Mesh
Standard	Proprietary	Proprietary	Proprietary
Network Size	Direct Connection 2 nodes 1 Hop	Small Networks 128 End Nodes 1 Coordinator 2 hops	Large Networks 8K Nodes 100+ Coordinators 100+ hops
Radio Support	All Microchip RF Transceivers	All Microchip RF Transceivers	All Microchip RF Transceivers
MCU Support	PIC16, PIC18, PIC24, SAMR21, SAMR30, SAMD20	PIC16, PIC18, PIC24, SAMR21, SAMR30 , SAMD20	PIC18, PIC24, SAMR21, SAMR30
Overhead	Very Low	Low	Low

Comparação dos Protocolos

	MiWi™ P2P	MiWi™ Star	MiWi™ Mesh
Code Size	~ 14KB	~ 16KB	~ 27KB
Non-Volatile Memory	Optional	Optional	Optional
Cost	Free	Free	Free
Certification	Local Government Certification Only (FCC, IC, ETSI …)	Local Government Certification Only (FCC, IC, ETSI …)	Local Government Certification Only (FCC, IC, ETSI …)

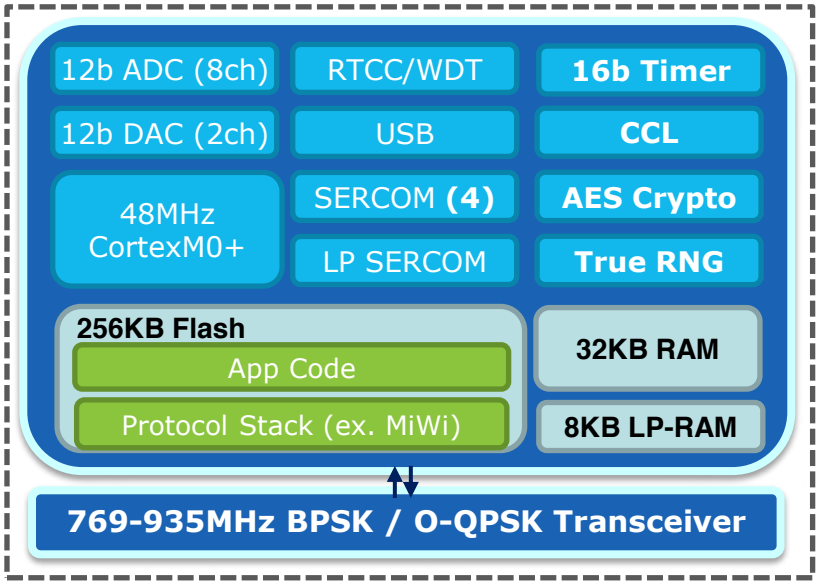
ATSAMR21

- **A cortex M0+ MCU + 2.4 GHz Transceiver in a single package!**
  ATSAMD21 + AT86RF233
- **Memories**
  - 64kB/128kB/256kB Flash
  - 8k/16k/32kB SRAM
- **Peripherals**
  - 4-SERCOM Interfaces
    - I^2C, SPI, and USART
  - 4x16 bit timers
  - 4-Ch 12-Bit ADC
  - Analog Comparator
- **Key Features**
  - HW AES
  - Antenna Diversity
  - Capacitive Touch HW engine (PTC)
  - USB FS Host & Device
  - Phase Measurement Unit (PMU)

Parameters	SAMR21
CPU Core	Cortex-M0+ @ 48MHz
Max PHY rate	250kbps (IEEE 802.15.4)
Frequency	2.4GHz
Stacks	Zigbee / BitCloud , MiWi
Applications	Lighting, Sensor Networks, Home Automation
Interfaces	SPI, UART
RF Tx/Rx peak	14mA/12mA @ 3.0V
Tx Pout	+4dBm
Rx Sensitivity	-99dBm
Sleep Mode	<4uA (RTC+RAM)
Package	7x7 QFN48 5x5 QFN32
Power Supply	1.8V – 3.6V
Temp Range	-40 to +125˚C
Availability	NOW

SAMR30 Single-chip Sub GHz

- A Cortex® M0+ MCU + Sub-GHz Transceiver in a single package!
  - ATSAML21 + AT86RF212B
- 256 KB flash / 32KB RAM
- 8KB Low Power Mode Retained RAM
- USB Host and Device
- Ultra Low Power Consumption
  - 700nA Typical with RTC
- Hardware AES crypto accelerators
- True Random Number Generator
- High performance ADC and analog peripherals for sensor nodes
- IEEE® 802.15.4-2003/2006/2011 compliant
- 769-935MHz band support

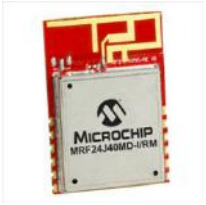


Transceiver ATA8510/15

QFN32 package
(5x5 mm)

- **Key Features**
  - Covers all ISM frequencies 315/433/868/915 MHz with one crystal)
  - Excellent RF Performance (Sensitivity -123dBm & Blocking 73dBc)
  - Output power: +14dBm max
  - Lowest current consumption
  - RX mode: 9.8mA (433MHz)
  - TX mode: 14.0mA (433MHz @ +10dBm)
  - OFF mode: 5nA
  - Lowest Bill-of-Material: 12 external components only

Módulos RF


	MRF24J40MA	MRF24J40MD	MRF24J40ME	MRF89xAM8A	MRF89xAM9A
Frequency	2.4G	2.4G	2.4G	868MHz	915Mz
Operating Voltage	2.4-3.6V	3.0-3.6V	3.0-3.6V	2.1-3.6V	2.1-3.6V
Tx Power	0 dBm	+19dBm	+19dBm	+10 dBm	+10 dBm
Rx Sensitivity	-94 dBm	-104 dBm	-104 dBm	-107 dBm	-105 dBm
Power Consumption	2 uA Sleep 19 mA Rx 23 mA Tx	10 uA Sleep 32 mA Rx 140 mA Tx	10 uA Sleep 32 mA Rx 140 mA Tx	0.1 uA Sleep 3 mA Rx 25 mA Tx	0.1 uA Sleep 3 mA Rx 25 mA Tx
Antenna	PCB	PCB	u.FL	PCB	PCB
Size	17.8 x 27.9 mm	22.9 x 33.0 mm	22.9 x 33.0 mm	17.8 x 27.9 mm	17.8 x 27.9 mm
MiWi Stack	P2P/Star/Mesh				
MCU Support	PIC 16/18/24				
Certifications	FCC/IC/EN			EN	FCC/IC

Transceivers Compatíveis 802.15.4

	AT86RF212B	AT86RF233	AT86RF215
Frequency	769…935	2.4G	389…510 779…1020 2400…2483
Operating Voltage	1.8-3.6V	1.8-3.6V	1.8-3.6V
Tx Power	10 dBm	4 dBm	14 dBm
Rx Sensitivity	-94 dBm	-104 dBm	-104 dBm
Power Consumption	0.2 uA Sleep 9.2 mA Rx 17.0 mA Tx	0.2 uA Sleep 6 mA Rx 13.8 mA Tx	30 uA Sleep 28 mA Rx 65 mA Tx
Pack	QFN32	QFN32	QFN48
Comments	IEEE 802.15.4-2006/2011	IEEE 802.15.4-2006/2011	IEEE 802.15.4g-2012; IEEE 802.15.4-2006/2011;

Kits de Desenvolvimento

MRF24J40MA
Part # AC164134-1

MRF24J40MB
Part # AC164134-2

ZENA™ Wireless Adapter with
Wireless Development Studio (WDS) Utility

Add RF to Microchip Dev Boards

SAMR21 Xplained Pro
(ATSAMR21-XPRO)

SAMR30 Xplained Pro
(ATSAMR30-XPRO)

Explorer 16 Dev Board
Part # DM240001-2

ATA8510-EK1

MiWi Demo Boards
(DM182016-2)

MRF89XAMxA
Part # AC164138-1

MRF89XAMxA
Part # AC164138-2

Como começar?

- Application Notes
  - MiMAC Application Note (AN1283)
  - MiApp Application Note (AN1284)
  - MiWi™ P2P Application Note (AN1204)
  - MiWi Application Note (AN1066)
- MiWi Código Fonte
  - Microchip Libraries for Applications c http://www.microchip.com/mplab/microchip-librariesfor-applications
  - ASF \ Atmel Studio 7
- MiWi Exemplos
  - http://www.microchip.com/design-centers/wireless-connectivity/embedded-wireless/802-15-4/software/miwi-protocol

MICROCHIP MASTERs 2019

Perguntas & Respostas

SMART | CONNECTED | SECURE

MICROCHIP

MICROCHIP MASTERs 2019

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MICROCHIP

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