

Intro to non-WiFi wireless protocols

An overview of commonly used non-WiFi protocols

Who am I?

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About Unimus

Unimus is a multi-vendor system for:

- Network Disaster recovery
- Change Management
- Network Automation
- Configuration Management
- Network Auditing & Compliance

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Note for posterity

If you find this presentation online in a .pdf, please watch the video

Proper explanations to every slide and much more information available

<https://www.youtube.com/c/TomasKirnak/videos>

Objective of this presentation

- Minulý rok sme robili deep-dive do fyzickej vrstvy WiFi.
- Tento rok však ideme do šírky.
- Pointa tejto prezentácie je aby ste dostali široký prehľad o tom aké nie-WiFi protokoly existujú.
- Taktiež si povieme čo je dôvod ich existencie.

Why Non-WiFi protocols exists at all

Goals of WiFi

- **WiFi** je short-range high-throughput protokol. WiFi je taktiež power-hungry a high-latency.
- V rôznych iných použitíach však môžeme potrebovať ďaleký dosah a nízky prietok.
- Alebo IoT batériové senzory môžu potrebovať bežať roky na batériu.
- Inokedy potrebujeme low-latency jednosmernú komunikáciu.

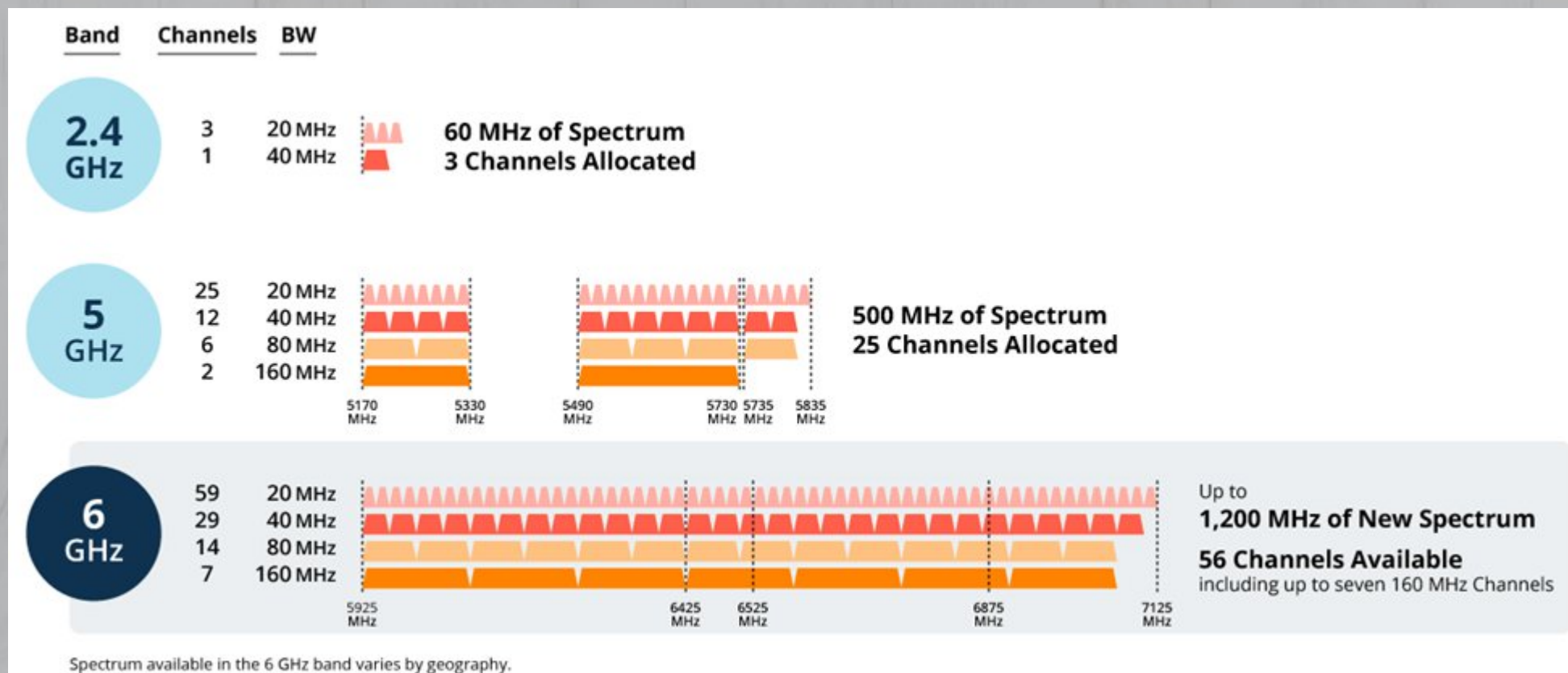
Balance of things

- Range
- Battery life
- Throughput
- Latency
- Reliability
- Scale

Každý protokol si vyberie 2-3 z týchto kritérií na úkor ostatných.

WiFi frequencies

- WiFi používa (relatívne) vysoké frekvencie.



Why go non-WiFi?

- WiFi (802.11) je výborný protokol pre prenos dát v IP sítach.
- IoT, telemetria, alebo real-time remote control však často potrebujú presne opak toho čo WiFi prináša.
- Existuje pre to kopa ďalších protokolov ktoré sú purpose-made na tento účel.

Useful notes to remember

- Každý protokol má výhody a nevýhody.
- If something sounds worse than WiFi - that's intentional.
- What problem is more important than speed?

HaLow (802.11ah)

WiFi but not as we know it

What is HaLow

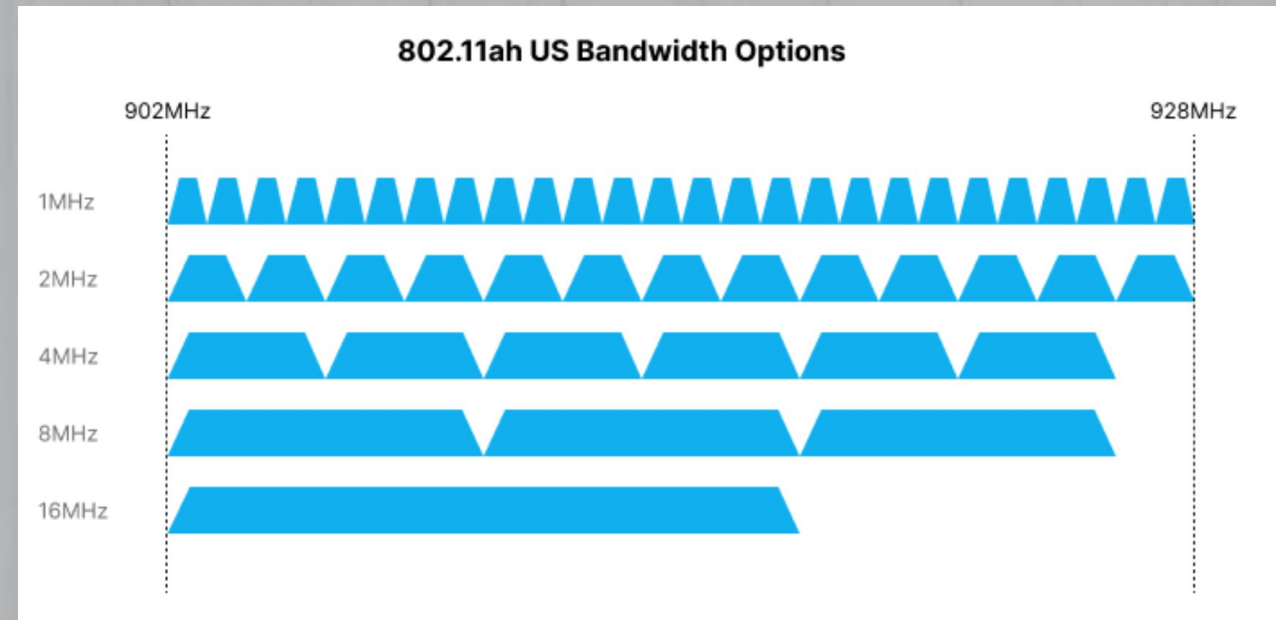
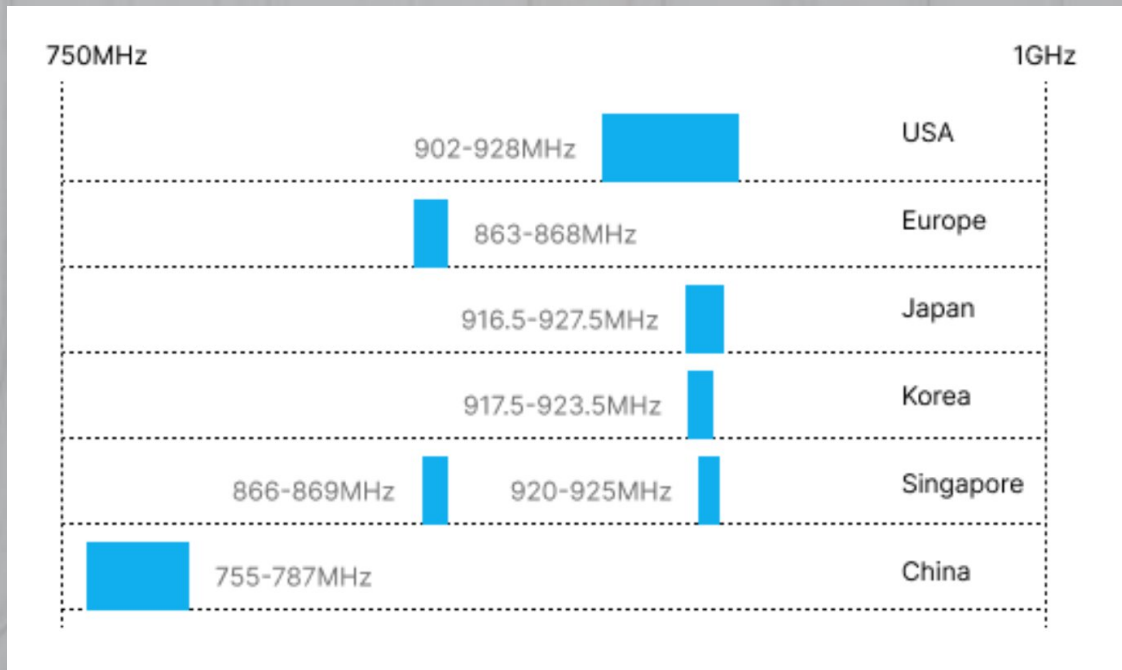
- Technicky stále hovoríme o WiFi.
- HaLow však používá 868/915 MHz

HaLow priorities

- Wi-Fi, but Slower, Farther, Cheaper.
- Obetujeme rýchlosť, avšak získavame:
 - Dosah
 - Power efficiency
 - Nižšia cena
 - Až 1.000 klientov na SSID

HaLow frequency range

- Sub-GHz, 868 alebo 915



HaLow MCS indexes

Modulation and coding schemes													
MCS index ^[b]	Spatial Streams	Modulation type	Coding rate	Data rate (Mbit/s) ^[11]									
				1 MHz channels		2 MHz channels		4 MHz channels		8 MHz channels		16 MHz channels	
				8 μ s GI ^[c]	4 μ s GI	8 μ s GI	4 μ s GI	8 μ s GI	4 μ s GI	8 μ s GI	4 μ s GI	8 μ s GI	4 μ s GI
0	1	BPSK	1/2	0.3	0.33	0.65	0.72	1.35	1.5	2.93	3.25	5.85	6.5
1	1	QPSK	1/2	0.6	0.67	1.3	1.44	2.7	3.0	5.85	6.5	11.7	13.0
2	1	QPSK	3/4	0.9	1.0	1.95	2.17	4.05	4.5	8.78	9.75	17.6	19.5
3	1	16-QAM	1/2	1.2	1.33	2.6	2.89	5.4	6.0	11.7	13.0	23.4	26.0
4	1	16-QAM	3/4	1.8	2.0	3.9	4.33	8.1	9.0	17.6	19.5	35.1	39.0
5	1	64-QAM	2/3	2.4	2.67	5.2	5.78	10.8	12.0	23.4	26.0	46.8	52.0
6	1	64-QAM	3/4	2.7	3.0	5.85	6.5	12.2	13.5	26.3	29.3	52.7	58.5
7	1	64-QAM	5/6	3.0	3.34	6.5	7.22	13.5	15.0	29.3	32.5	58.5	65.0
8	1	256-QAM	3/4	3.6	4.0	7.8	8.67	16.2	18.0	35.1	39.0	70.2	78.0
9	1	256-QAM	5/6	4.0	4.44	—	—	18.0	20.0	39.0	43.3	78.0	86.7
10	1	BPSK	1/2 x 2	0.15	0.17	—	—	—	—	—	—	—	—
11	1	1024-QAM	3/4	4.5	5.0	9.75	10.83	20.25	22.5	43.87	48.75	87.75	97.5
12	1	1024-QAM	5/6	5.0	5.55	—	—	22.5	25.0	48.75	54.17	97.50	108.33

When is HaLow useful?

- Large IoT sensor networks
- Vehicle monitoring (warehouses, farms, etc.)
- Obstacle penetration
- Long-range low-bandwidth links
- Links over water
- Co-existence with other high-throughput 802.11 protocols

HaLow hardware

- PCIe HaLow karty sa dajú kúpiť za 5-15 Euro
- HaLow AP / client cca 50-70 Euro



HaLow connection model

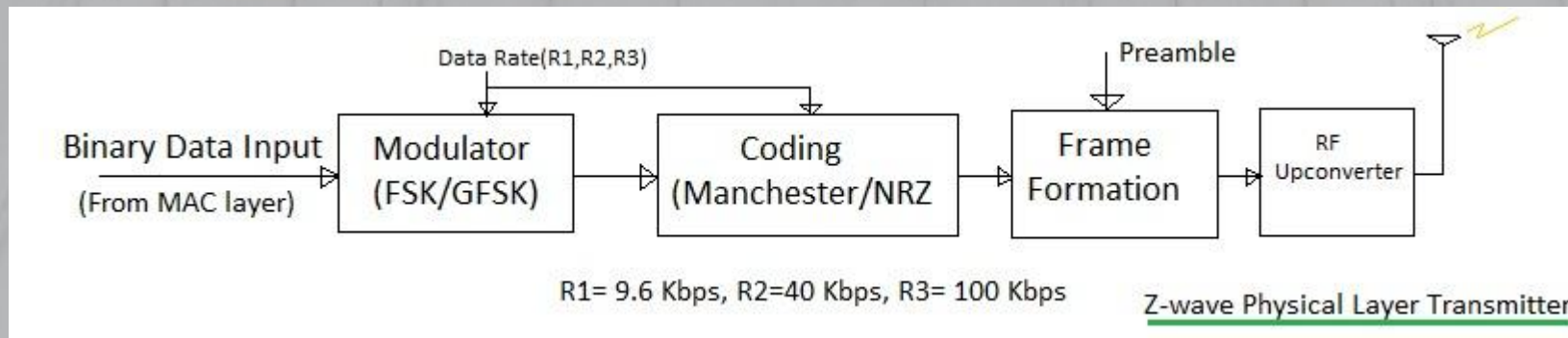
- AP – Station model
- Same as WiFi
- IP (v4 alebo v6) na vyšších vrstvách.
- Kedže HaLow je 802.11 platí všetko ostatne čo aj pri “klasickom” WiFi.

Z-Wave

Low-Power Mesh

What is Z-Wave

- Už nie WiFi. IoT “siet” pre senzory, ovládače, monitoring, atď.
- Fyzická vrstva už nie je 802.11 ale proprietárna.



Z-Wave priorities

- IoT / sensor mesh network.
- Obetujeme rýchlosť aj celý IP stack, ale:
 - Dosah
 - Power efficiency
 - Odolnosť interferencií
 - Mesh

Z-Wave frequency range

- Sub-GHz, 868 alebo 915

Specification	Z-wave support
Standard	ITU-T G.9959 (PHY and MAC)
RF Frequency Range	868.42 MHz in Europe, 908.42 MHz in US

Z-Wave coding and speed

Modulation and Coding Format

Data Rate Designation	Modulation	Coding	separation Symbols
R1	FSK	Manchester	40 KHz+/-10% Binary
R2	FSK	NRZ	40 KHz+/-10% Binary
R3	GFSK (BT=0.6)	NRZ	58 KHz+/-10% Binary

Z-Wave Data Rate and Accuracy

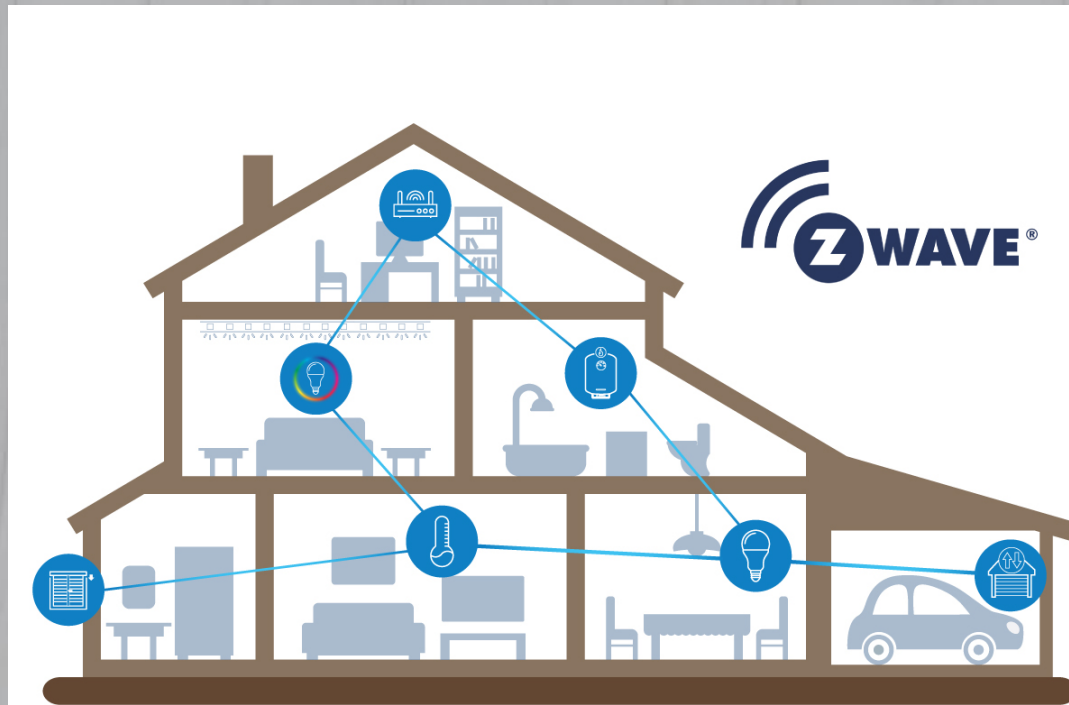
Data Rate Designation	Bit Rate	Symbol Rate	Accuracy
R1	9.6 Kbps	19.2 Kbaud	+/- 27 ppm
R2	40 Kbps	40 Kbaud	+/- 27 ppm
R3	100 Kbps	100 Kbaud	+/- 27 ppm

Z-Wave connection model

- Primary controller
- Node-y ktoré majú špecifické role
- Mesh routing s hop limitmi

When is Z-Wave useful?

- Domáce IoT siete, kontrola a manažment budov, atd.
- Automatizácia



Z-Wave hardware

- Z-Wave controller 20-60 Euro
- Nekonečné množstvo rôznych senzorov, IoT zariadení



Zigbee

The next level of Z-Wave

What is Zigbee

- Zigbee je evolúcia Z-Wave.
- Open, mesh, scalable, complex
- Versioned in capabilities (like WiFi)
- Forward and backward compatible
- Fyzická vrstva je 802.15.4.

Zigbee priorities

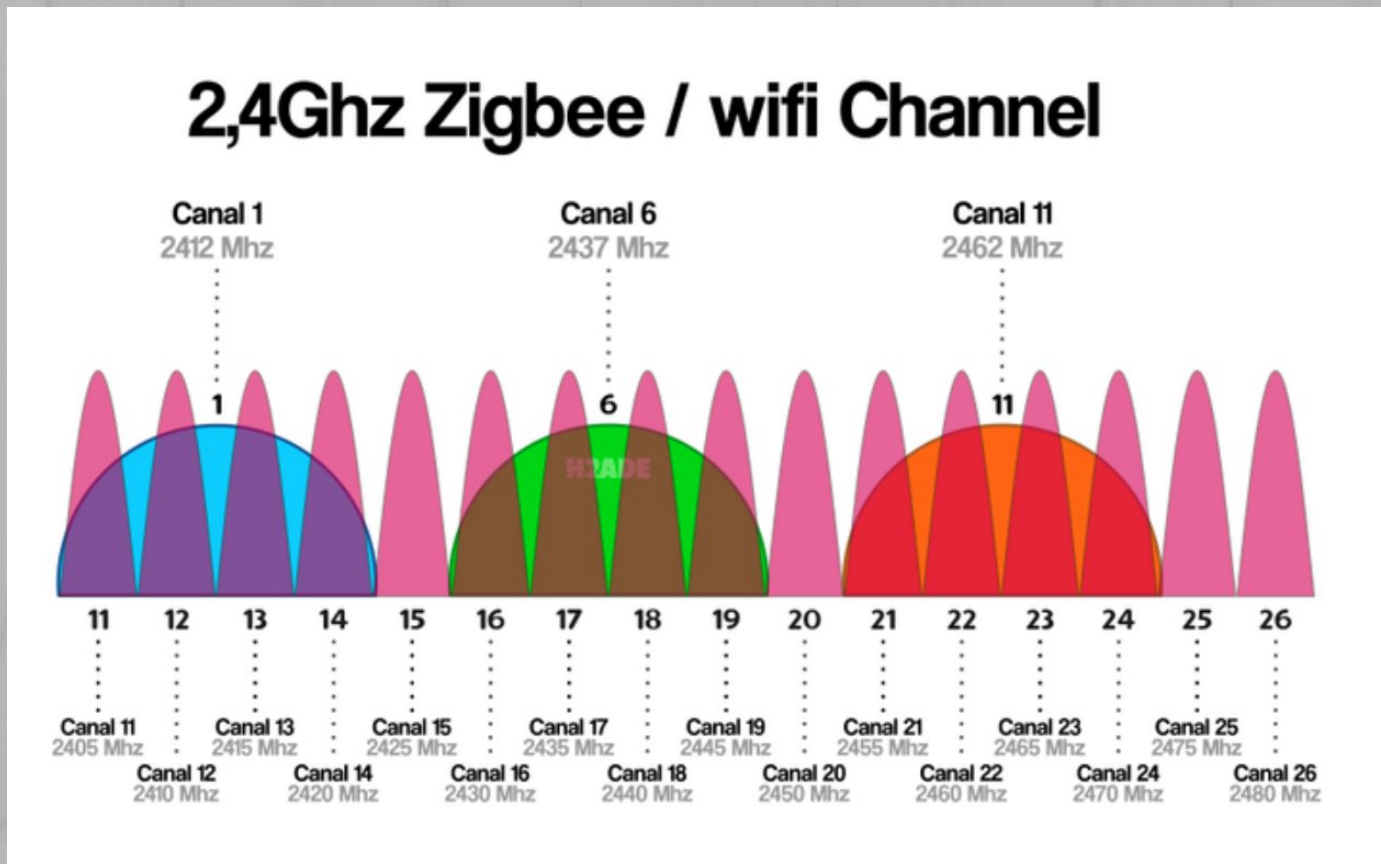
- Be better than Z-Wave
- 2.4 GHz or 868/915 MHz
- Podpora viac zariadení
- Better power management

Zigbee versions

- Podobné ako WiFi protocols, aj Zigbee ma verzie
- (802.11n, 802.11ac, atď.)
- Dnes už prosím nekupujte nič staršie ako Zigbee 3.0
- 3.0 a 3.1 sú dnes najpopulárnejšie
- Zigbee 3 pracuje na 2.4 GHz

Zigbee channels

- Zigbee je backwards aj forwards compatible (ako WiFi)



Zigbee 4

- Zigbee 4 bolo vydané iba minulý rok
- Pridáva podporu pre 868/915 MHz
- Ak chcete aj 2.4 aj 868, musíte mať koordinátor ktorý to podporuje



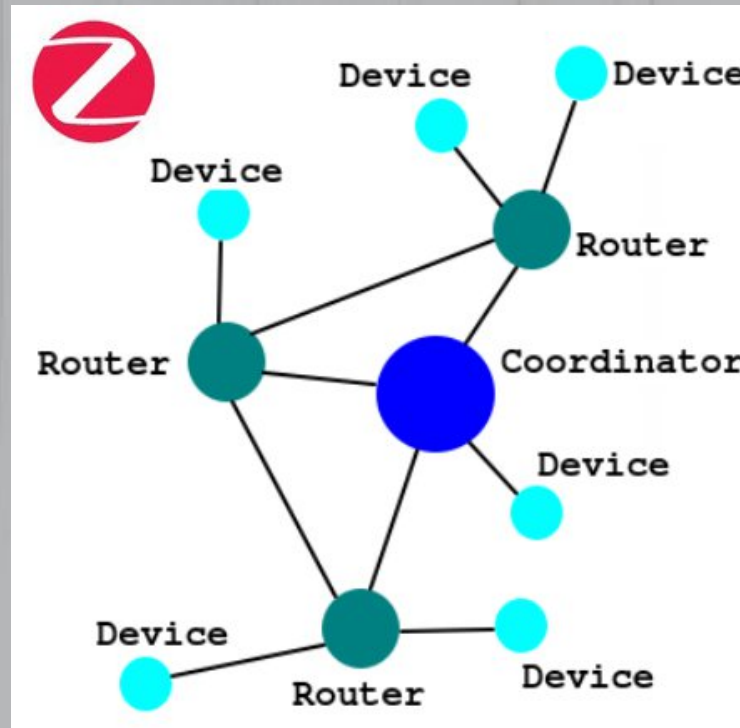
Zigbee coding and speed

- Keďže Zigbee PHY je 802.15.4, táto tabuľka je pre tento protokol.
- Zigbee má teda 2.5x prietok Z-Wave na 2.4 GHz.
- Limit okolo 8 správ za sekundu.

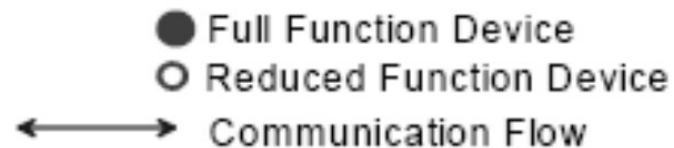
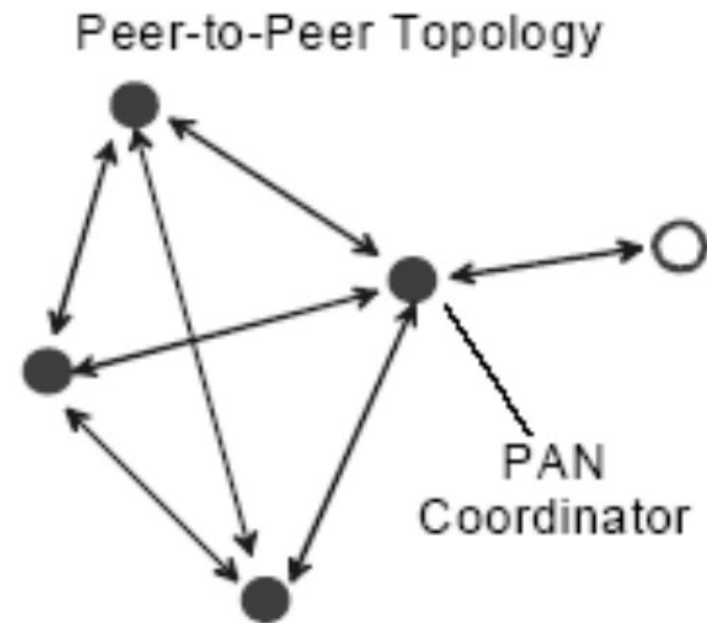
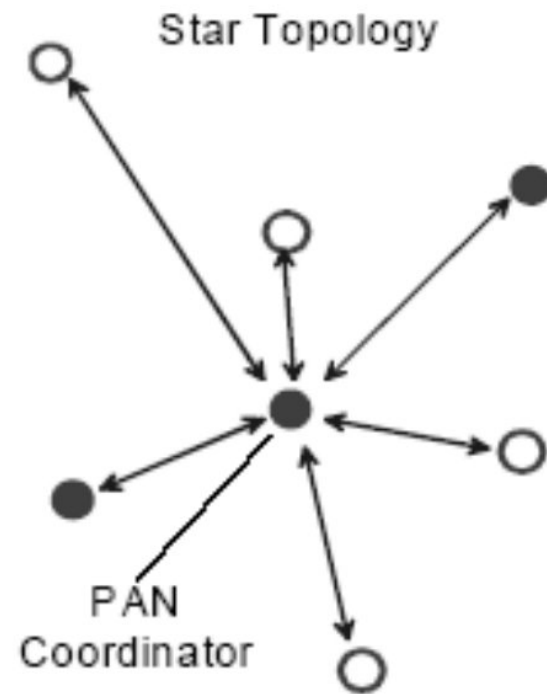
	Frequency Band (MHz)		
	868.3	902-928	2400-2483.5
# of Channels	1	10	16
Bandwidth (kHz)	600	2000	5000
Data Rate (kbps)	20	40	250
Symbol Rate (ksps)	20	40	62.5
Unlicensed Geographic Usage	Europe	Americas (approx)	Worldwide
Frequency Stability	40 ppm		

Zigbee connection model

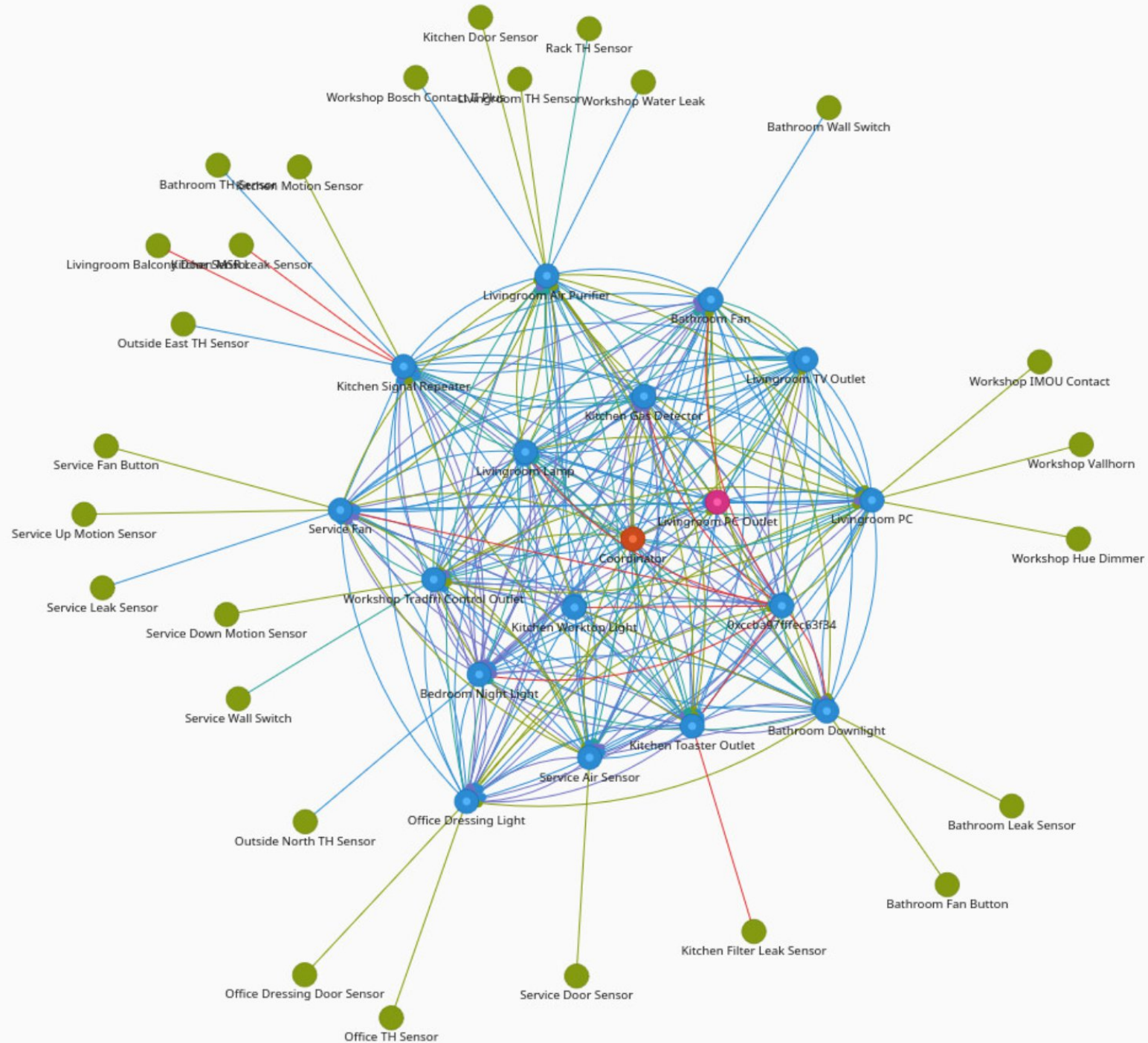
- Coordinator (USB alebo Ethernet konektivita)
- Router
- End Device



Zigbee topologies



Zigbee in reality



When is Zigbee useful?

- Same as Z-Wave, but
 - Better
 - Newer

A look at a real Zigbee network

Actual Zigbee network demo

Z-Wave hardware

- Z-Wave controller 20-60 Euro
- Nekonečné množstvo rôznych senzorov, IoT zariadení



Thread & Matter

Where the future is headed

What is Thread and Matter

- Thread a Matter sú rodinka protokolov pre budúcnosť IoT
- Thread je PHY
- Matter je application layer / control protocol

Thread/Matter priorities

- Next generation protocols
- Be better than Zigbee
- Brings back IP stack (IPv6)
- Improves resiliency

What is Thread

- PHY (Fyzická) vrstva, stále 802.15.4.
- Low-power mesh
- Natívne IPv6
- Dizajnované pre moderné IoT

Thread coding and speed

- Keďže Thread PHY je 802.15.4, táto tabuľka je pre tento protokol.
- Thread má teda rovnaký prietok ako Zigbee.
- Limit okolo 8 správ za sekundu.

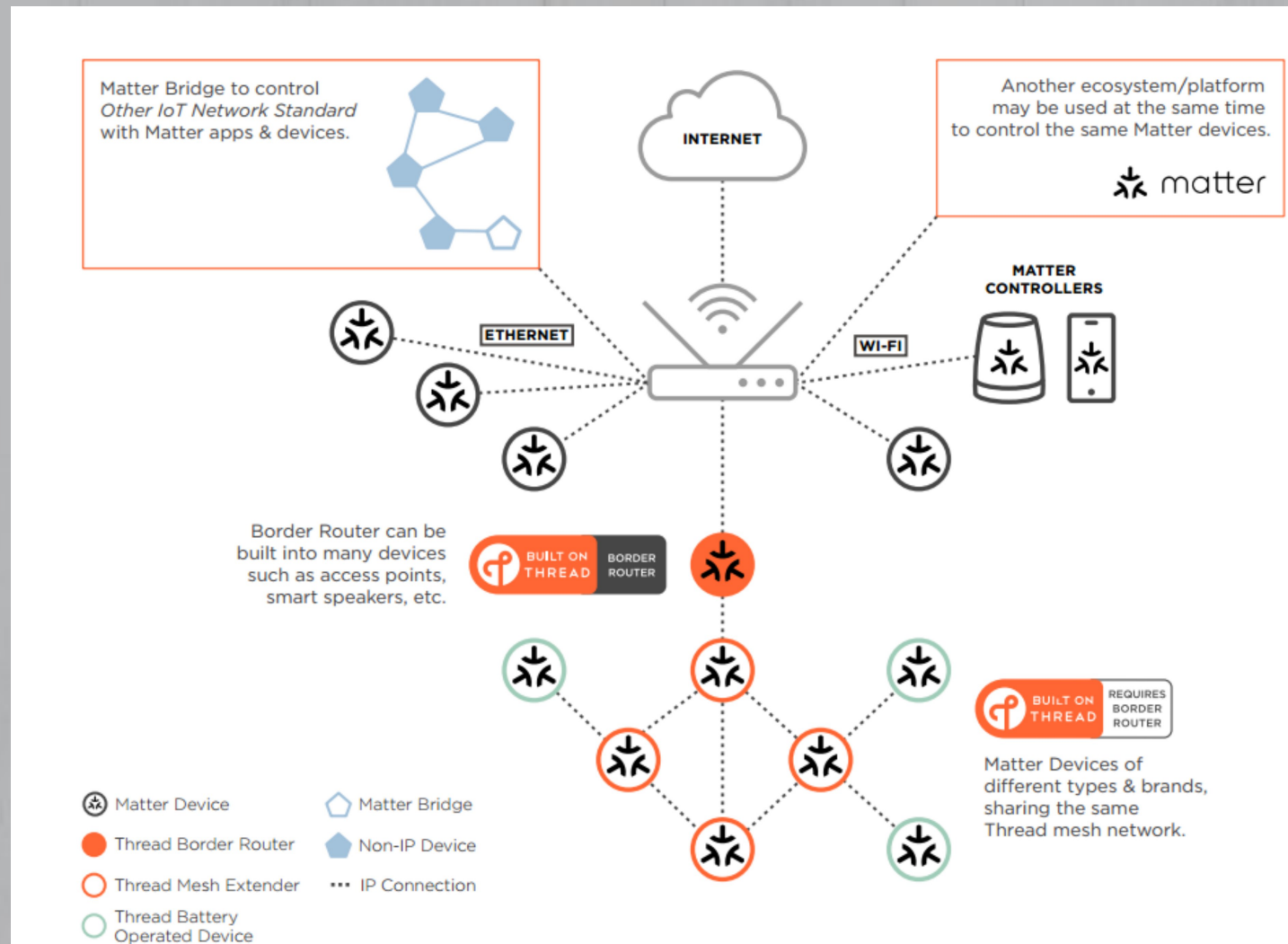
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Thread connection model

- Leader
 - Router
 - End Device
 - Border Router
-
- Automatický výber role (vs. statický Coordinátor na Zigbee)
 - Lepšia resiliency proti výpadkom

Thread can actually be wired too

- Spomenuli sme ze Thread je osobitný protokol od Matter.
- Thread sa teda dá použiť aj na Ethernet-e.



What is Matter

- Unifikujúci komunikačný protokol (nie PHY vrstva, vyššie).
- Cez Matter ovládame jednotlivé IoT zariadenia – teda posielame im príkazy čo robiť.
- Matter je vendor-neutral.

When is Thread/Matter useful?

- Rovnaké ako Zigbee, ale next-gen
- Zatiaľ je na trhu ale menej Thread/Matter zariadení ako Zigbee.
- Zigbee je viac mature ecosystem, Thread/Matter novší.

LoRa

When the Network Stops Being a Network

LoRa priorities

- Extreme range
- Extreme noise resiliency
- Chirp spread spectrum PHY
- Very very large “networks”
- Flexible, can offer very low stable latency

LoRa is different

- Until now, we assumed:
 - Bidirectional communication
 - Centralized control
 - Predictable latency
 - A “network” you can debug
- LoRa breaks all of these.

What is LoRa then?

- Pri LoRa vieme hovoriť o 2 veciach:
- LoRa - radio modulation (PHY)
- LoRaWAN - MAC + network protocol (upper layers)

LoRa frequency range

- Whatever you want... but most commonly:
- 433 MHz
- 868 / 915 MHz
- 1.1 GHz
- 2.4 GHz

LoRa connection model 1

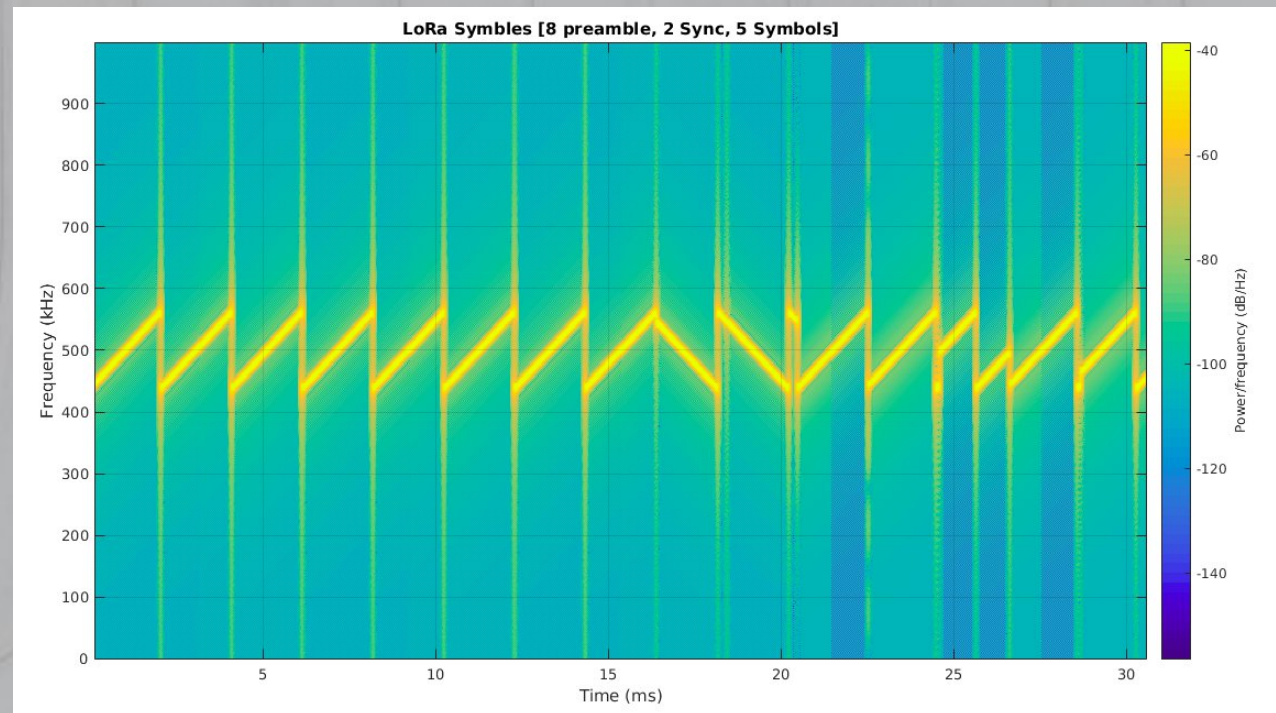
- LPWAN (Low-Power Wide Area Network)
- Star topology
- Devices talk to gateways
- Gateways forward to network servers

LoRa connection model 2

- Class A - uplink-only, lowest power
 - Class B - scheduled receive windows
 - Class C - always listening
-
- Neexistuje “asociácia” ako u WiFi.
 - S LoRa zariadeniami nekomunikujete priamo, ale čakáte kedy vám pošlú dáta.

Chirp modulation

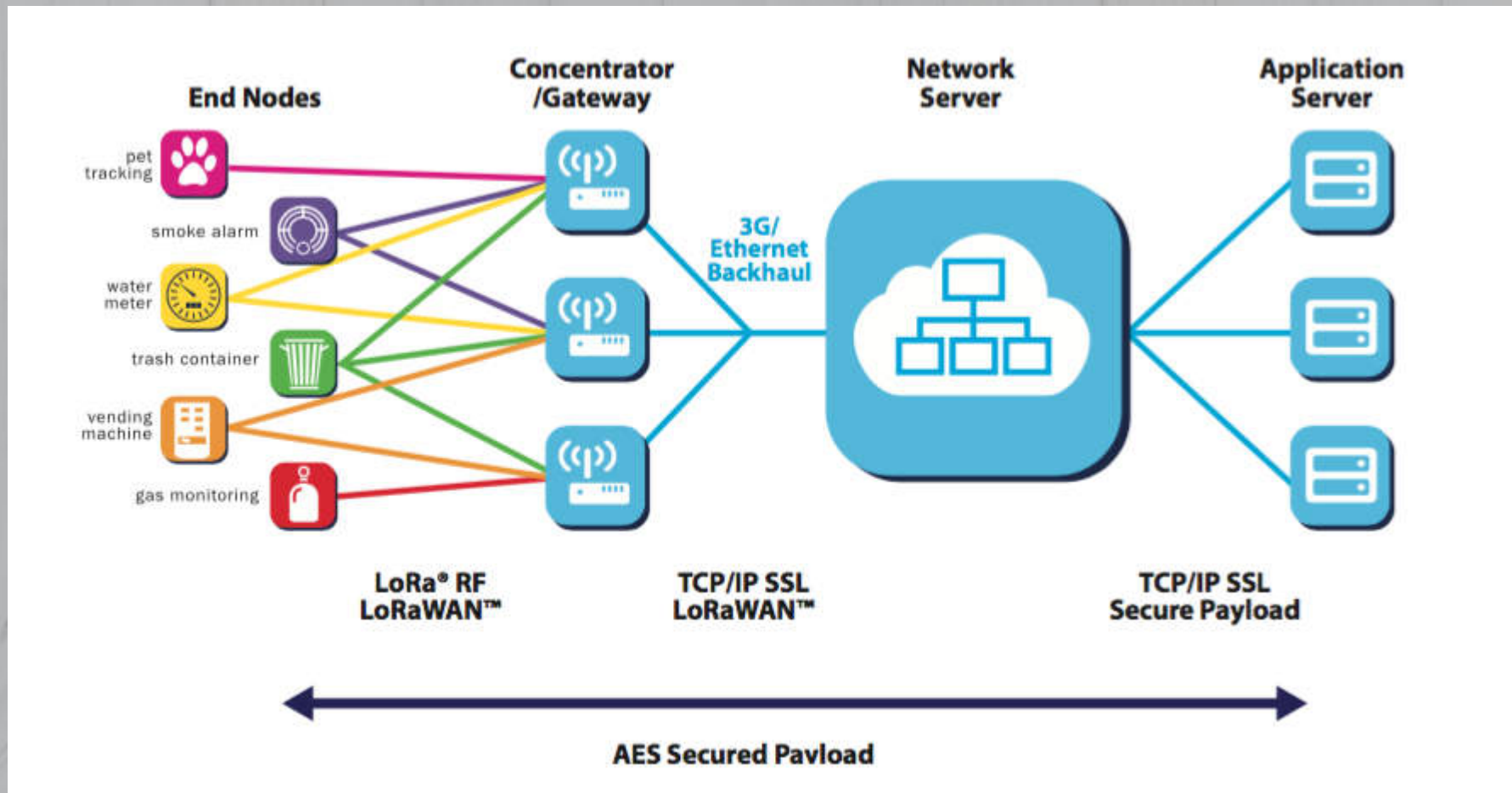
- LoRa PHY používa “chirp” moduláciu
- Toto umožňuje komunikáciu aj keď je noise väčší ako signál.



Real use-cases of LoRa

- LoRaWAN (thousands of sensors)
- Meshtastic (LoRa PHY)
- ExpressLRS (LoRa PHY)

LoRaWAN



Meshtastic

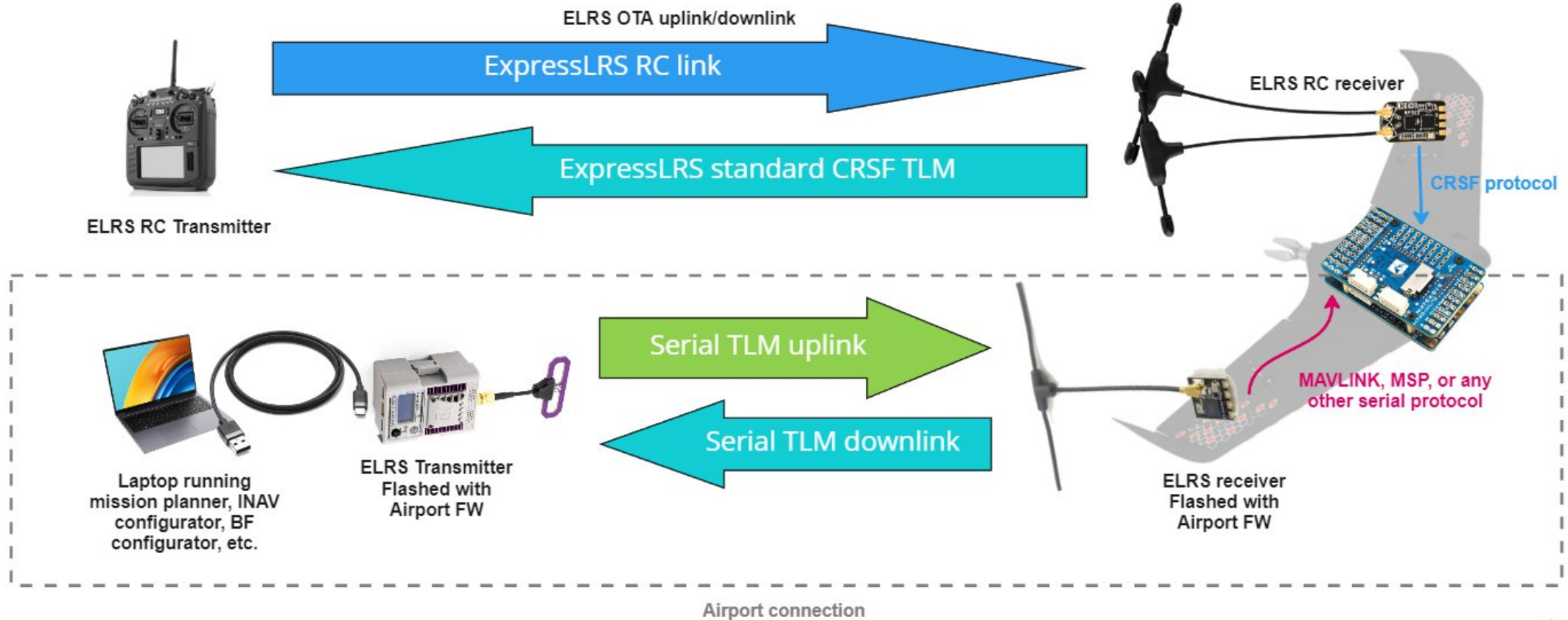
- Meshtastic is a decentralized wireless off-grid mesh networking LoRa protocol.
- The main goal of the project is enabling low-power, long-range text communication.



ExpressLRS

- RC control link pre UAV (drony, lietadla, atd').
- ExpressLRS aims to provide the best, high refresh radio control link while maintaining a maximum achievable range at that rate with low latency.
- Vast support of hardware in both 900 MHz and 2.4 GHz frequencies.

ExpressLRS



Magic of ExpressLRS

- Doručenie control packet-ov do 100km v správnych podmienkach.
- Extrémne nastaviteľné – od short range low latency cez long range high latency.
- Noise and jamming resiliency

That's it, thank you!

Q&A session