Inteligentne budynki

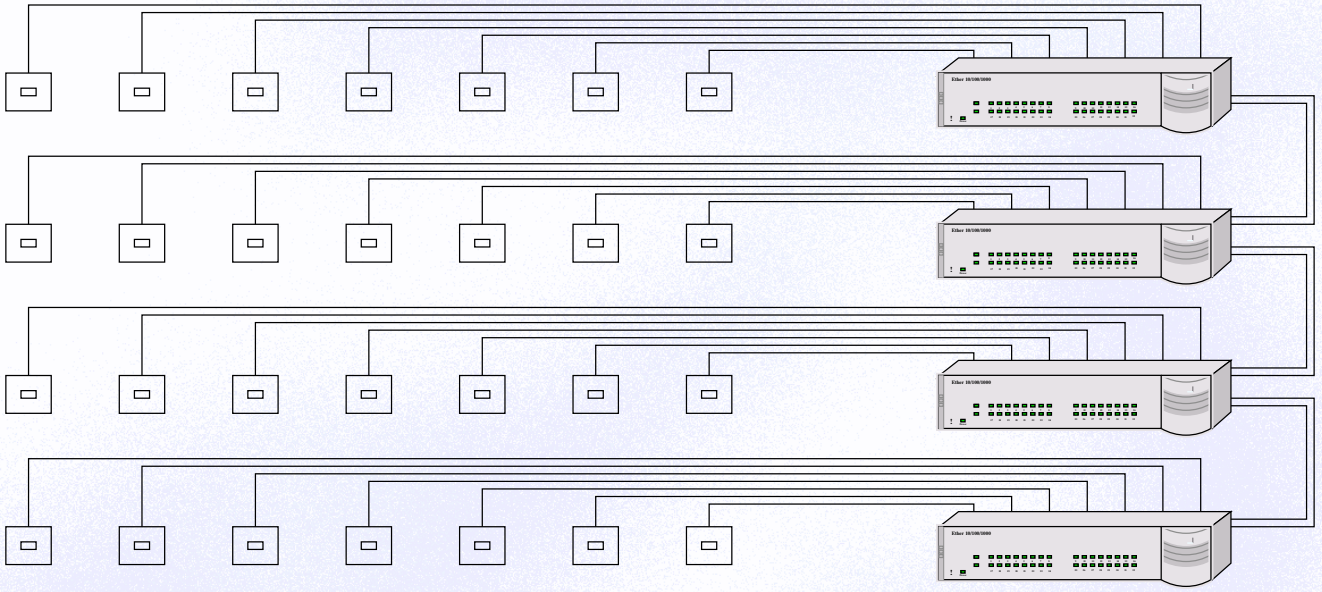
mgr inż. Jerzy Sobczyk

Sieci sterujące

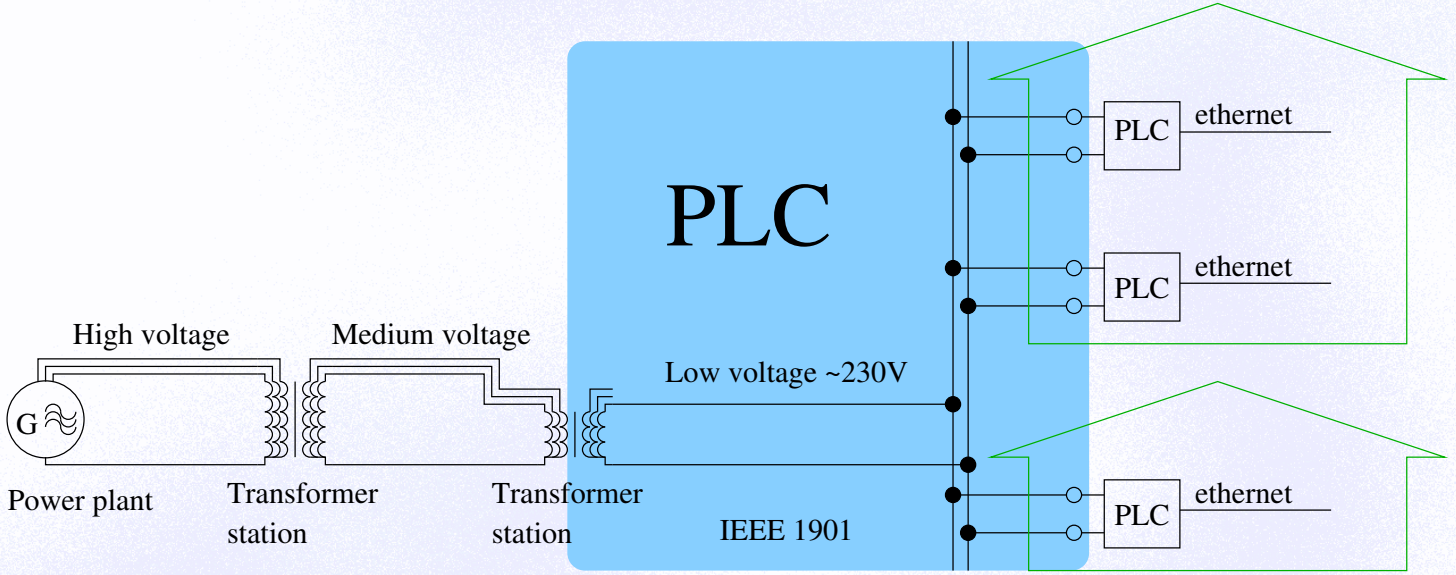
Plan wykładu

- sieć Ethernet,
- połaczenia po sieci energetycznej - PLC
- zasilania po kablu Ethernet - PoE,
- sieci bezprzewodowe WiFi,
- Bluetooth,
- Z-Wave,
- ZigBee,
- telefonia komórkowa GSM,
- BACnet,
- Modbus,
- CANbus,

Okablowanie strukturalne Ethernet



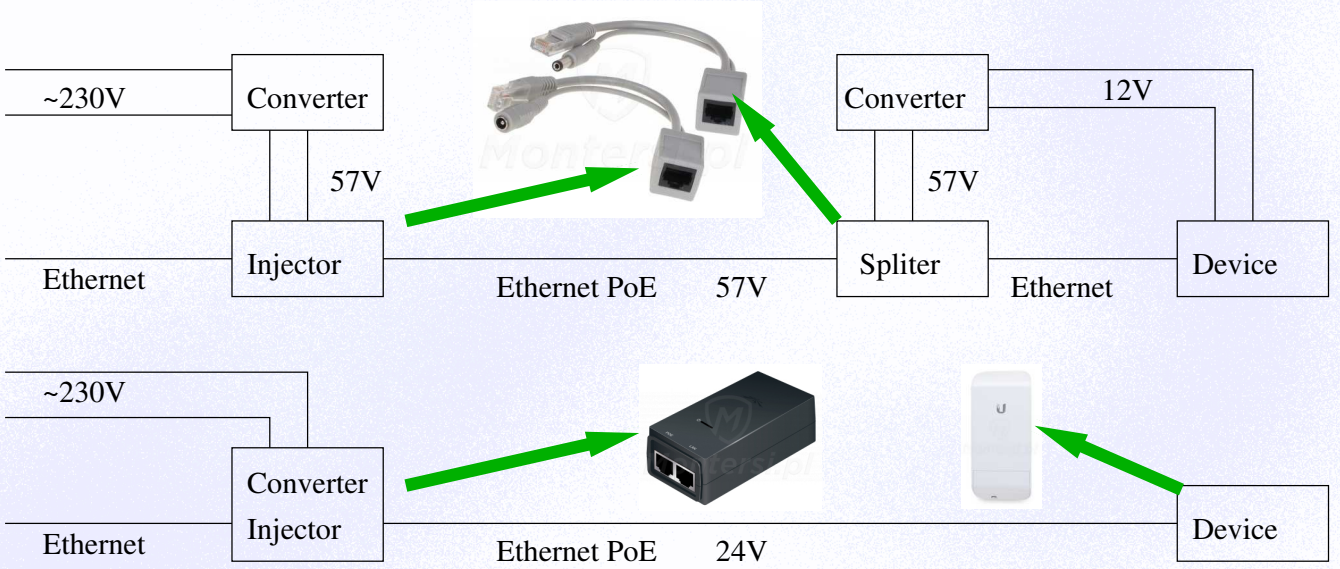
Transmisja po sieci energetycznej PLC



PLC - HomePlug

	HomePlug			
	v1.0	AV	AV2	Green PHY
year	2001	2005	2012	2010
rate	14 Mb/s	200 Mb/s	1300 Mb/s	10 Mb/s
encryption	AES 128			
interoperability	NO	YES		
carrier frequency	4.5-21 MHz	2-30 MHz	2-86 MHz	2-86 MHz
distance	>100 km in theory practically to nearest transformer station			

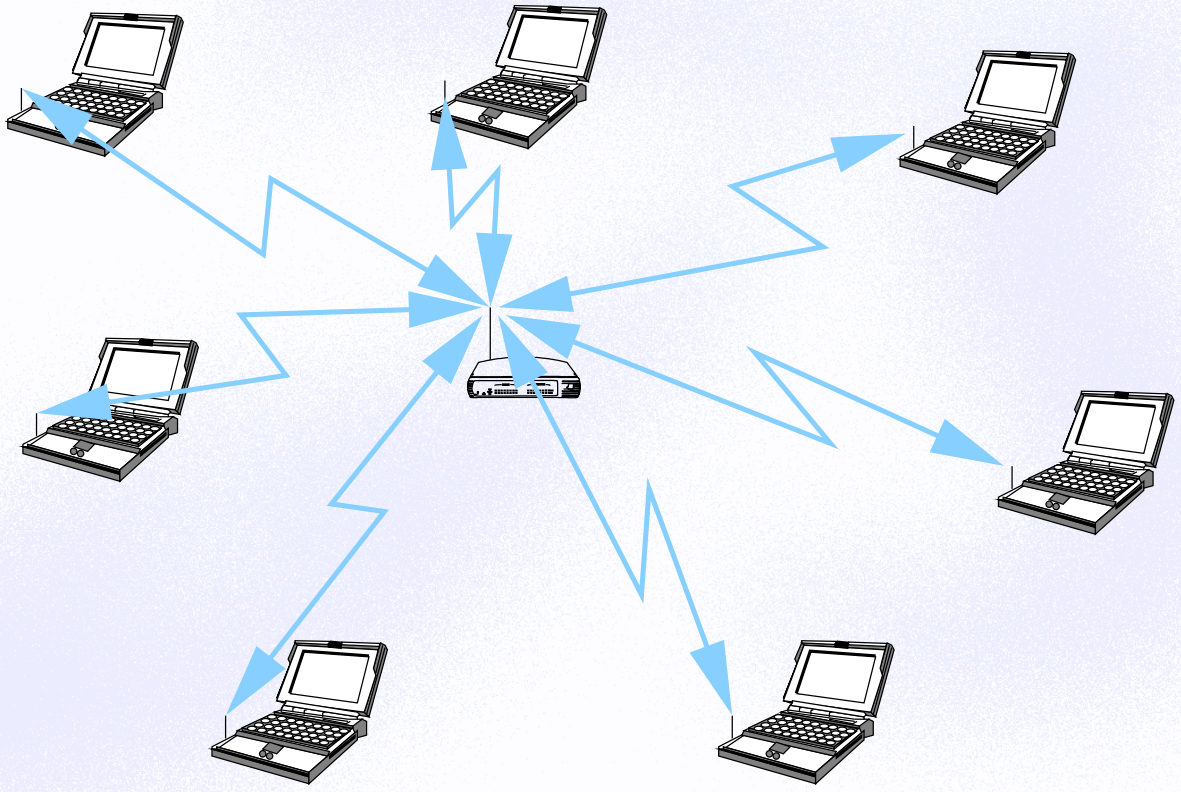
Zasilanie po kablu Ethernet - PoE



PoE - Power over Ethernet

	802.3af Type 1 PoE	802.3at Type 2 PoE+	802.3bt Type 3 4PPoE	802.3bt Type 4 4PPoE
Power supplied [W]	15,40	30,0	60	100
Power delivered [W]	12,95	25,50	51	71
Voltage on supply [V]	44,0–57,0	50,0–57,0	50,0–57,0	52,0–57,0
Voltage delivered [V]	37,0–57,0	42,5–57,0	42,5–57,0	41,1–57,0
Max. current [mA]	350	600	600/pair	960/pair
Max. cable resistance [Ohm]	20	12.5	12.5	12.5
Cabling category	3 and 5	5	5	5

Tryb infrastukturalny WiFi



Historia WiFi

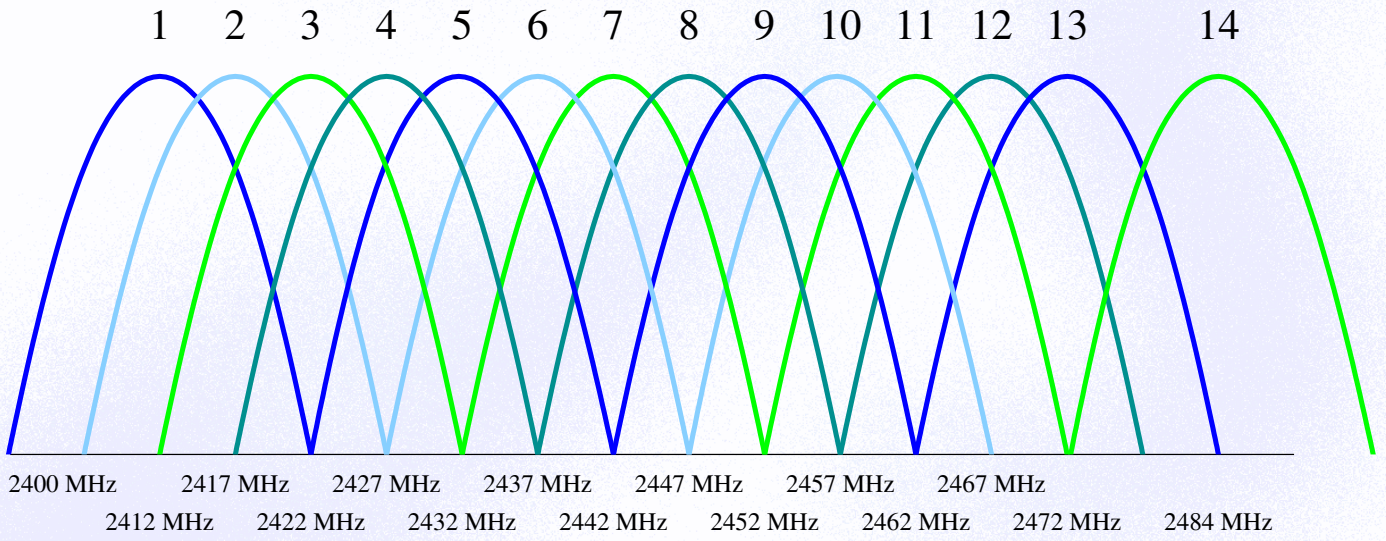
Year	Standard	Band	Speed	Measured speed	Remarks
1997	IEEE 802.11	2,4 GHz	1 and 2 Mb/s		
	IEEE 802.11a	5 GHz	54 Mb/s		
1999	IEEE 802.11b	2,4 GHz	5,5 and 11 Mb/s		
2003	IEEE 802.11g	2,4 GHz	54 Mb/s	(23 Mb/s)	
2009	IEEE 802.11n	2,4 i 5,0 GHz	450 Mb/s	(200..240 Mb/s)	
2012	IEEE 802.11ad	60 GHz	7 Gb/s		
2013	IEEE 802.11ac	5,0 GHz	1,3 Gb/s	(222..720 Mb/s)	
2014	IEEE 802.11af	54..790 MHz	26..569 Mb/s		
2019	IEEE 802.11ay	60 GHz	20..40 Gb/s		300..500 m
2020 ?	IEEE 802.11ax	1..6 GHz	5..10 Gb/s		
2021 ?	IEEE 802.11be	2,4; 5; 6 GHz	40 Gb/s		

Kompromis odległość/szybkość WiFi 802.11b

	Speed			
	high	medium	standard	low
	11 Mb/s	5.5 Mb/s	2 Mb/s	1 Mb/s
Open space	160 m	270 m	400 m	550 m
Semi open space	50 m	70 m	90 m	115 m
Closed space	25 m	35 m	40 m	50 m

Podział pasma WiFi 2.4 GHz

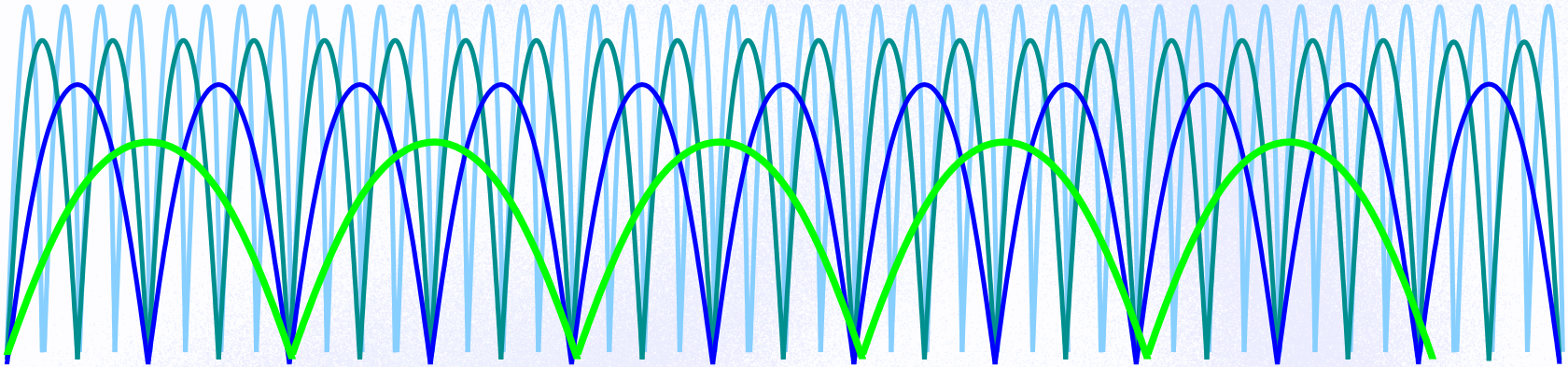
802.11 b



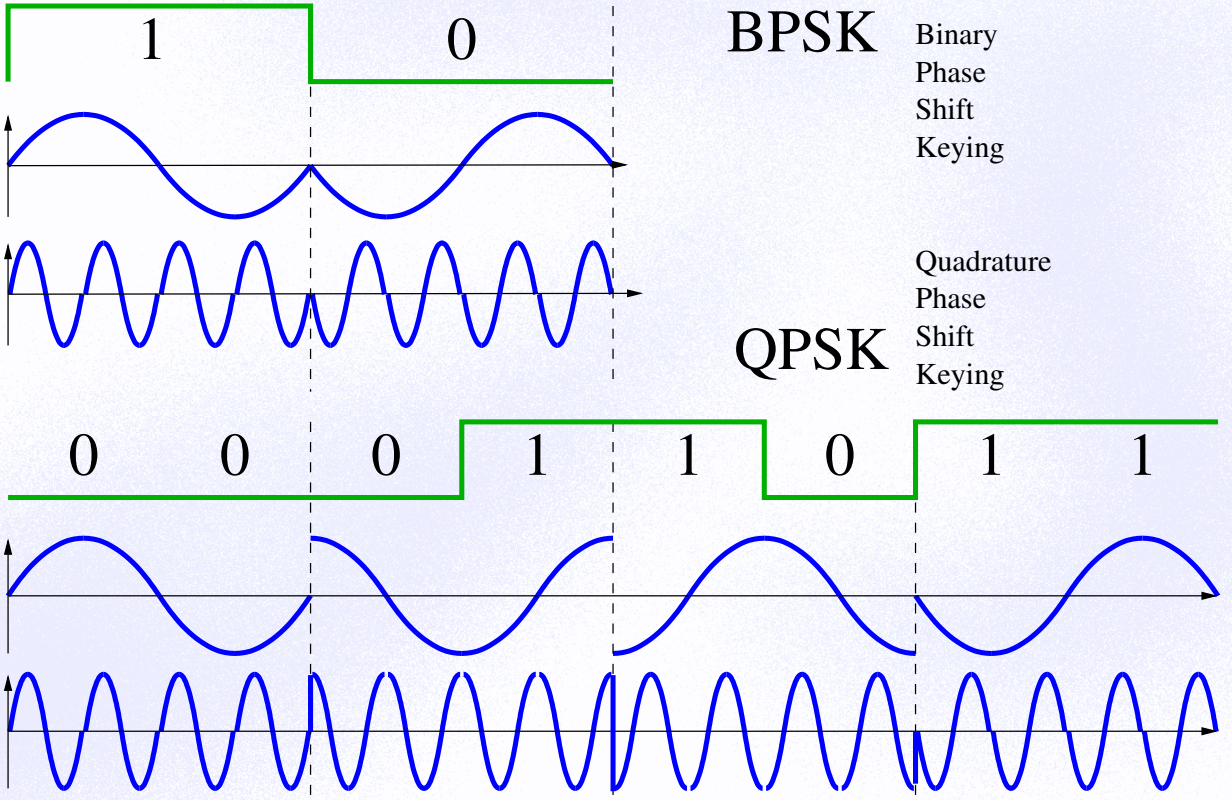
USA – 1–11 EMEA – 1–13 Israel – 5–8 Japan – 1–14

Podział pasma WiFi 5 GHz

5 GHz



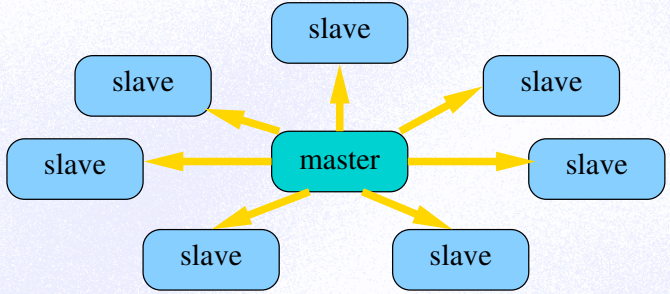
Modulacja WiFi



Bluetooth

- 2.4 GHz band
- split to 79 channels
- 1 MHz for each channel

Class	1	2	3
Power	100 mW	2.5 mW	1 mW
Range	100 m	10 m	1 m



Warianty Bluetooth

Version	Speed (theoretical)	Remarks
1.0	21 kb/s	
1.1	124 kb/s	
1.2	328 kb/s	
2.0 + EDR	2.1 Mb/s (3 Mb/s)	Enhanced Data Rate
2.1 + EDR		simplification of pairing, support for future NFC and smaller power consumption
3.0 + HS	24 Mb/s (3 MB/s)	High Speed
3.1 + HS	40 Mb/s (5 MB/s)	High Speed
4.0 + LE	1 Mb/s	Low Energy - drastically smaller power consumption due to lower speed but distance was extended to 100 m
4.1		standard for IoT wearables
4.2		faster transfer, better security and IoT support
5.0	2 Mb/s wearables 50 Mb/s others	version unification, extended effective distance to 140 m

Profile Bluetooth

Nr.	Profile	Nr.	Profile
1	Advanced Audio Distribution Profile (A2DP)	19	Human Interface Device Profile (HID)
2	Attribute Profile (ATT)	20	Headset Profile (HSP)
3	Audio/Video Remote Control Profile (AVRCP)	21	Intercom Profile (ICP)
4	Basic Imaging Profile (BIP)	22	LAN Access Profile (LAP)
5	Basic Printing Profile (BPP)	23	Mesh Profile (MESH)
6	Common ISDN Access Profile (CIP)	24	Message Access Profile (MAP)
7	Cordless Telephony Profile (CTP)	25	OBject EXchange (OBEX)
8	Device ID Profile (DIP)	26	Object Push Profile (OPP)
9	Dial-up Networking Profile (DUN)	27	Personal Area Networking Profile (PAN)
10	Fax Profile (FAX)	28	Phone Book Access Profile (PBAP, PBA)
11	File Transfer Profile (FTP)	29	Proximity Profile (PXP)
12	Generic Audio/Video Distribution Profile (GAVDP)	30	Serial Port Profile (SPP)
13	Generic Access Profile (GAP)	31	Service Discovery Application Profile (SDAP)
14	Generic Attribute Profile (GATT)	32	SIM Access Profile (SAP, SIM, rSAP)
15	Generic Object Exchange Profile (GOEP)	33	Synchronization Profile (SYNCH)
16	Hard Copy Cable Replacement Profile (HCRP)	34	Synchronisation Mark-up Language Profile (SyncML)
17	Health Device Profile (HDP)	35	Video Distribution Profile (VDP)
18	Hands-Free Profile (HFP)	36	Wireless Application Protocol Bearer (WAPB)

Z-Wave

- Z-Wave was developed by Zensys, a Danish company in 1999.
- In 2005 Danfoss, Leviton and other firms formed Z-Wave Aliance.
- Z-Wave is using unlicensed band in 800-900 MHz range.
- Transmission speed is 9,4; 40 or 200 kb/s depending on the series of the chip.
- Distance 30..40 m indoors up to 100 m outdoors.
- Up to 232 devices in one network.
- Source routing with up to 4 hops between nodes.
- It uses frequency shift keying with Manchester encoding.
- CSMA/CA
- ITU-T G.9959

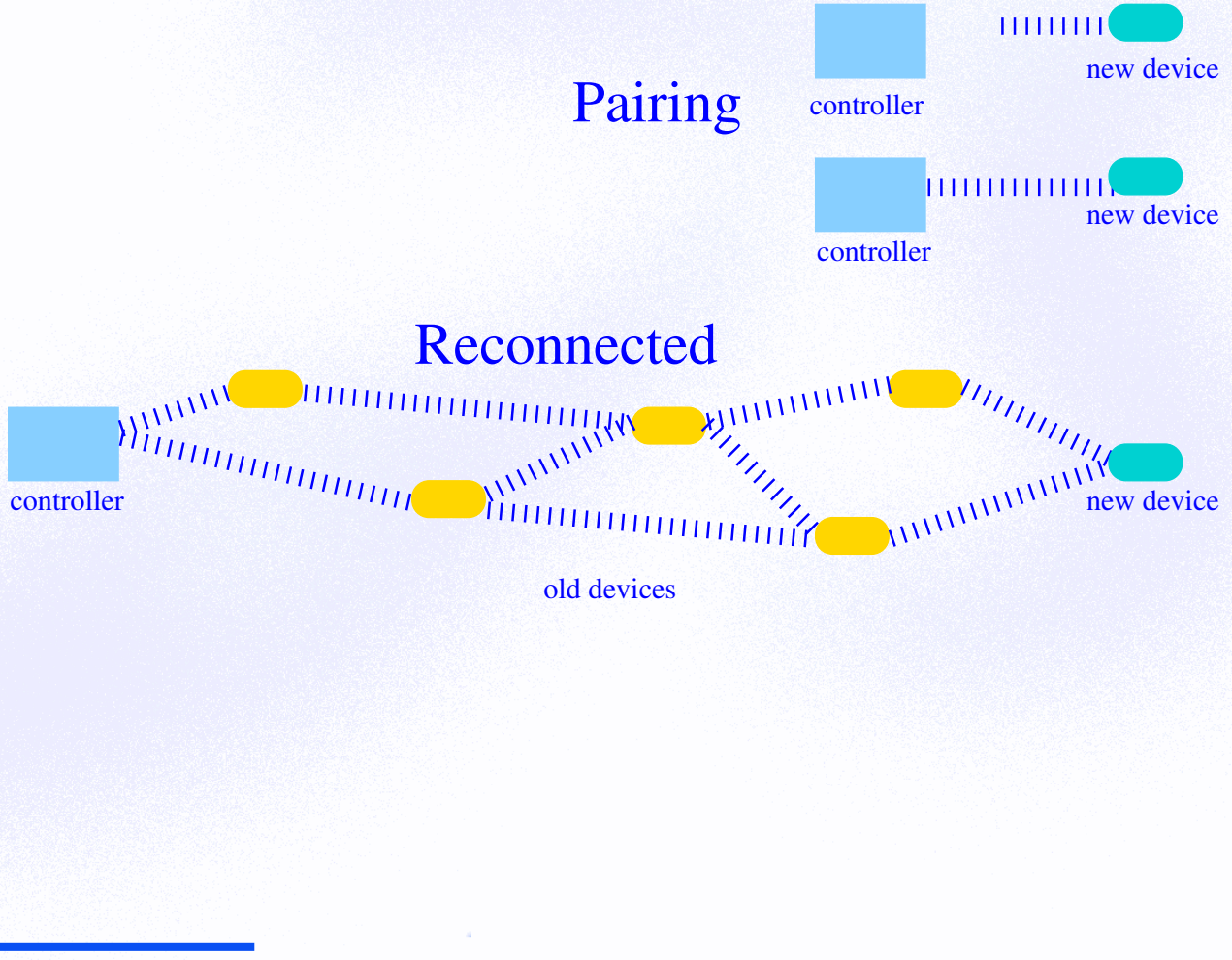
Częstotliwości Z-Wave

Frequency MHz	Countries
865.2	India
869	Russia
868.4	China, Singapore, South Africa
868.40, 868.42, 869.85	CEPT Countries (Europe and other countries in region), French Guiana
908.40, 908.42, 916	USA, Canada, Argentina, Guatemala, The Bahamas, Jamaica, Barbados, Mexico, Bermuda, Nicaragua, Bolivia, Panama, British Virgin Islands, Suriname, Cayman Islands, Trinidad and Tobago, Colombia, Turks and Caicos Islands, Ecuador, Uruguay
916	Israel
919.8	Hong Kong
919.8, 921.4	Australia, New Zealand, Malaysia, Brazil, Chile, El Salvador, Peru
919–923	South Korea
920–923	Thailand
920–925	Taiwan
922–926	Japan

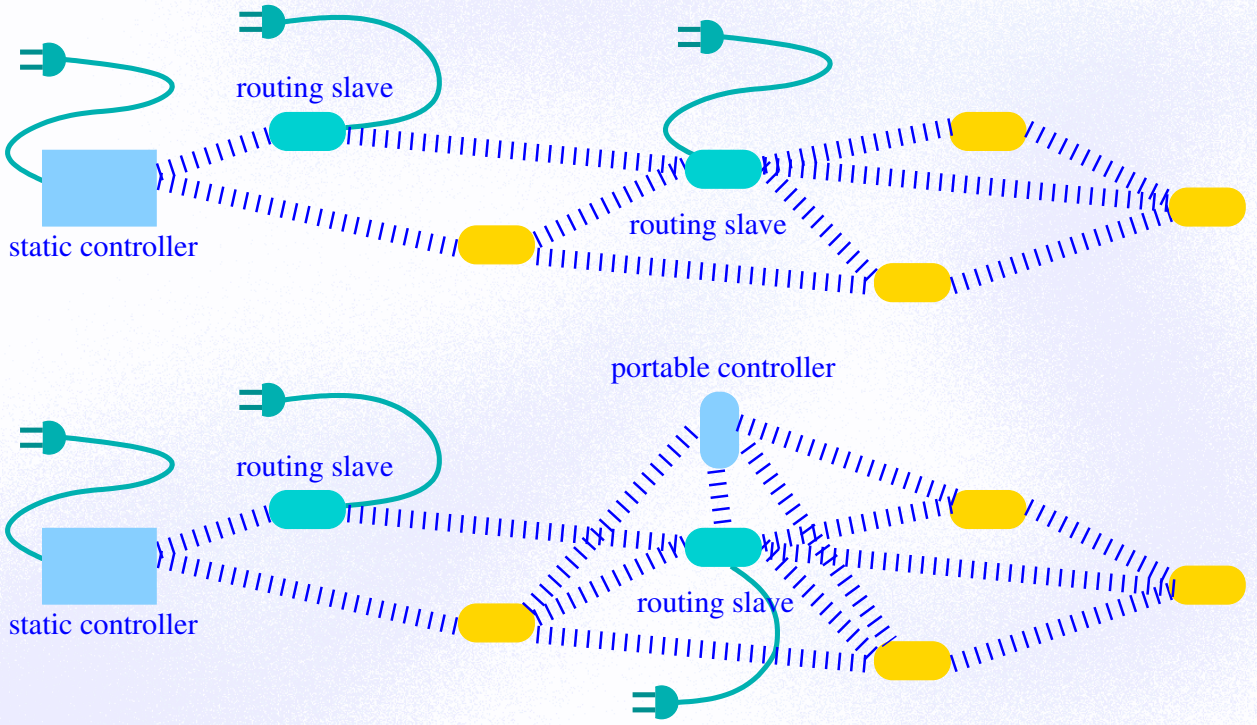
Szybkosci Z-Wave

	Rate designation		
	R1	R2	R3
Bit rate	9.6 kb/s	40 kb/s	100 kb/s
Symbol rate	19.2 kBaud	40 kBaud	100 kBaud
Center freqency	908.42 MHz	908.40 MHz	916 MHz
Modulation	FSK	FSK	GFSK
Coding	Manchester	NRZ	NRZ
Deviation	$\pm$20 kHz	$\pm$20 kHz	$\pm$29 kHz

Z-Wave - dodawanie urządzenia



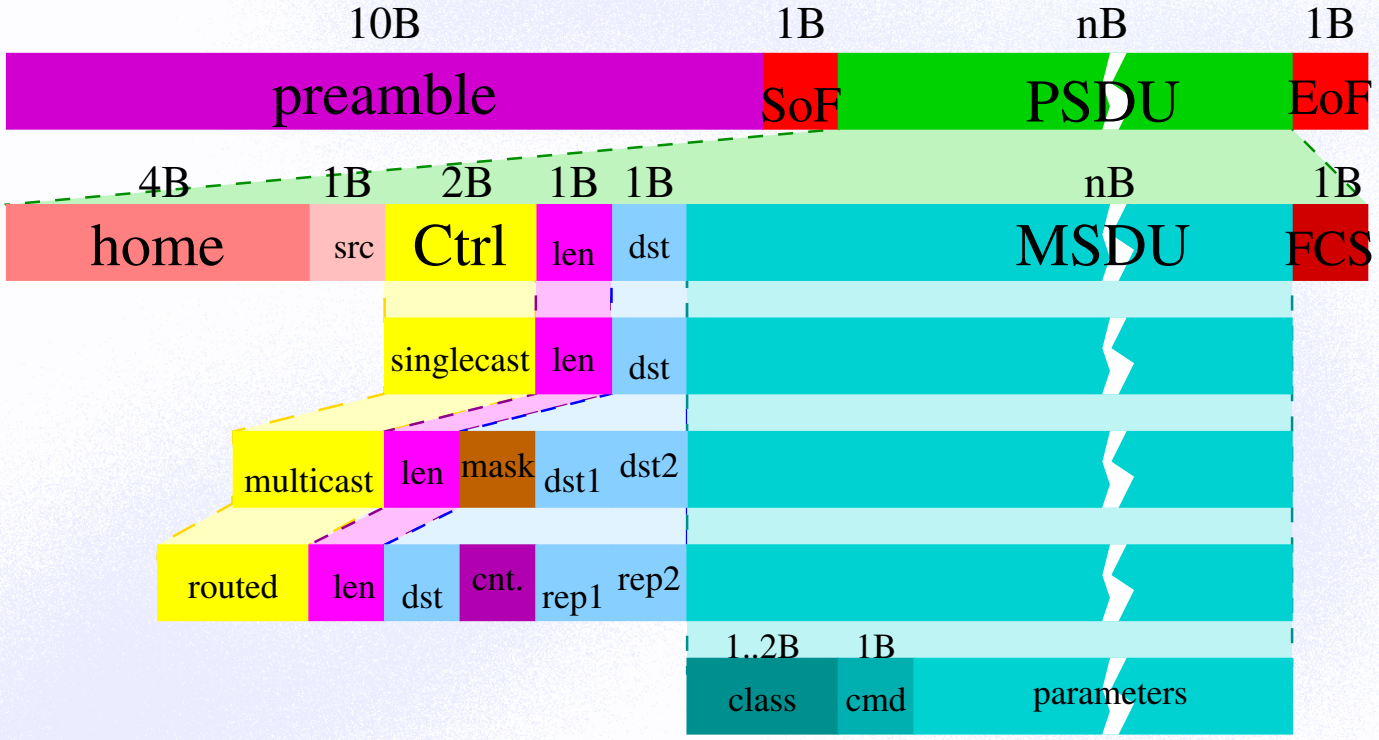
Z-Wave - wiele sterowników



Z-Wave - typy urządzeń

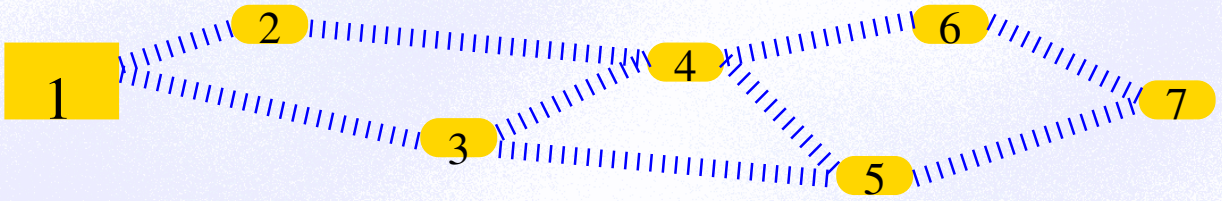
Type	Controller	Routing slave	Slave
Neighbours	knows all neghbours	knows all neghbours	knows all neghbours
Routing	has a complete routing table	has partial routing table	has no routing table
Functions	can communicate with every device if route exists	can reply to the node which he has received the message from and can send unsolicited messages to a number of predefined nodes he has a route	can only reply to the node which it has received the message from and can not send unsolicited messages
Power	preferrably mains powered	preferrably mains powered	battery operated or mains powered
Sleep	does not sleeep	can't sleep	can sleep a lot

Z-Wave - format ramki



Z-Wave - wytyczanie trasy

Source node	Destination node 1	2	3	4	5	6	7
1		1	1	0	0	0	0
2	1		0	1	0	0	0
3	1	0		1	1	0	0
4	0	1	1		1	1	0
5	0	0	1	1		0	1
6	0	0	0	1	0		1
7	0	0	0	0	1	1	



ZigBee

- Devloped by ZigBee Aliance
- Compliant with IEEE 802.15.4-2011 standard
- Uses 2.4 GHz band with 16 channels 2 MHz wide each.
- AES-128 encryption
- Distance 75-100 m indoor and over 300 m outdor.
- Datarate 250 kb/s
- Network size up to 65000 nodes.
- Topology: self-forming and self-healing mesh.
- ZigBee Green Power - energy harvesting, transmit only devices.

ZigBee - historia

- 2002 Zigbee Aliance creation
- 2004 ZigBee v.1.0 draft
- 2006 ZigBee v.2.0
- 2007 ZigBee Pro
- 2015 ZigBee Pro 2015
- 2016 ZigBee v.3.0
- 2017 Dotdot : communication protocol

ZigBee - urządzenia

Device type	Description
Zigbee Coordinator	The most capable device, the coordinator forms the root of the network tree and may bridge to other networks. There is precisely one Zigbee coordinator in each network since it is the device that started the network originally It stores information about the network, including acting as the trust center and repository for security keys.
Zigbee Router	As well as running an application function, a router can act as an intermediate router, passing data on from other devices.
Zigbee End Device	Contains just enough functionality to talk to the parent node (either the coordinator or a router); it cannot relay data from other devices. This relationship allows the node to be asleep a significant amount of the time thereby giving long battery life. A ZigBee end device requires the least amount of memory and thus can be less expensive to manufacture than a router or coordinator.

ZigBee Green Power

Device type	Description
Green Power Device	A self-powering, energy-harvesting device that implements the Green Power feature. These devices communicate using a compact message format and **all messages are one-way (out only). They are not end devices and cannot receive commands.**
Green Power Proxy	Zigbee device, which additionaly implements proxy functionality of the Green Power feature. The proxy translates Green Power frames to Zigbee Cluster Library frames and acts as an intermediate node between the Green Power Devices and sinks on the Zigbee network.
Green Power Sink	Any device that can be controlled by or receive data from a GPD (for example, a light or a server device). A Green Power Sink can only be implemented on a standalone End Device.
Green Power Combo Basic	A combination device that only implements the basic Green Power combo functionality, for both sink and proxy within a single device.

Z-Wave kontra ZigBee

	Z-Wave	ZigBee
Number of nodes in one network	232	65000
Speed	9.6-100 kb/s	40-250 kb/s
Encryption	AES-120	AES-128
Distance	30-100 m	10-20 m
Radio band	800-900 MHz	2.4 GHz
Standard	ITU-T G.9959	IEEE 802.15.4-2011

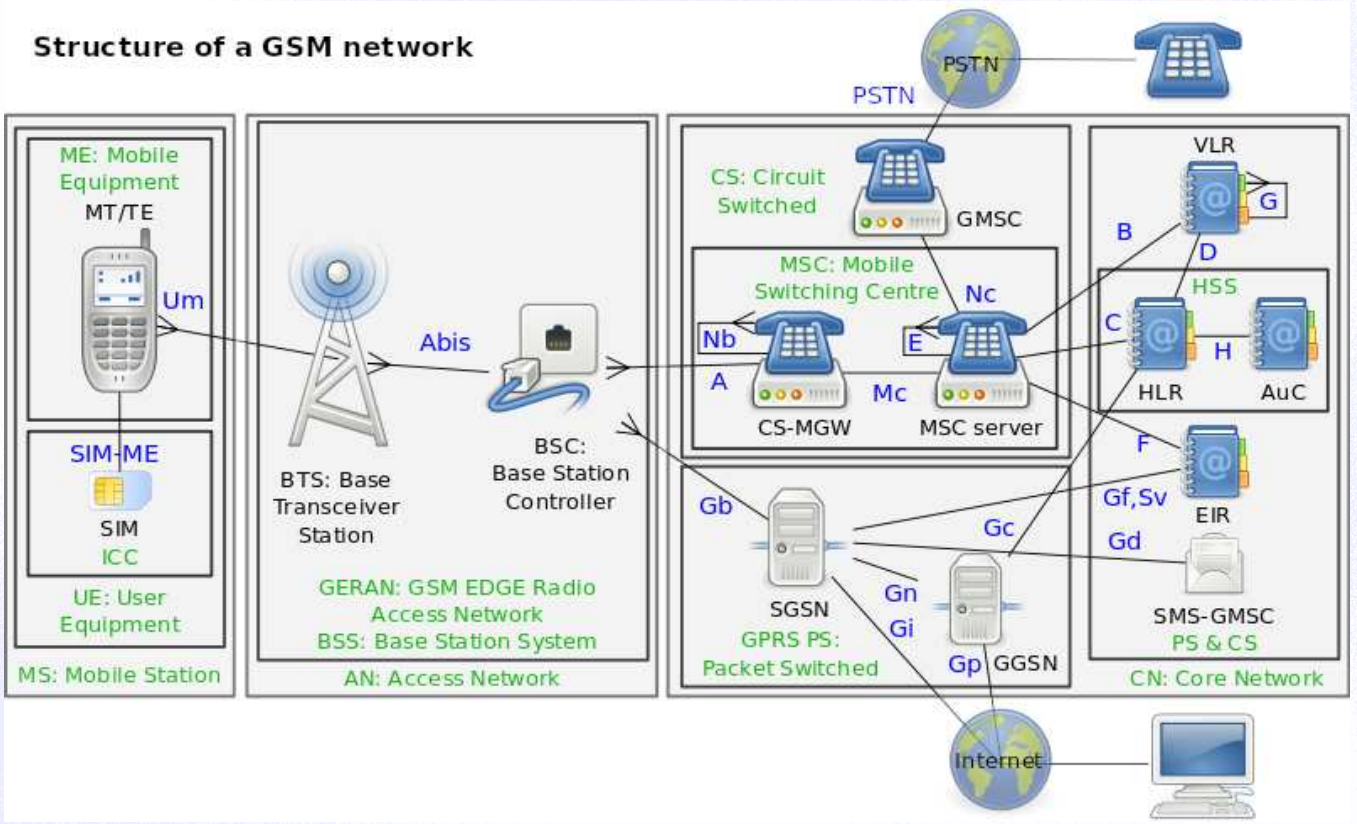
GSM

- Global System for Mobile Communications
- Developed by European Telecommunications Standards Institute
- First deployed in Finland 1991
- It offers global service for voice calls, data transfer, short messages and multimedia messages.
- User is identified by IMSI - International Mobile Subscriber Identity number stored on SIM - Subscriber Identity Module.

GSM - hostoria

- 1983 - begin of the work
- 1986 - reservation of 900 MHz band
- 1990 - 2G
- 1991 - first GSM call in Finland
- 1992 - first SMS
- 1993 - first 1800 MHz network
- 1995 - SMS, fax and data transmissions avaliable commecially
- 1995 - 10 000 000 subscribers
- 1997 - GPRS specification
- 2000 - GPRS services
- 2001 - 3G UMTS network
- 2002 - MMS
- 2003 - EDGE
- 2004 - 1 000 000 000 subscribers
- 2007 - 3G HSPA
- 2008 - 3 000 000 000 subscribers
- 2008 - 4G LTE standard
- 2018 - 5G standard
- 2020 - 5G

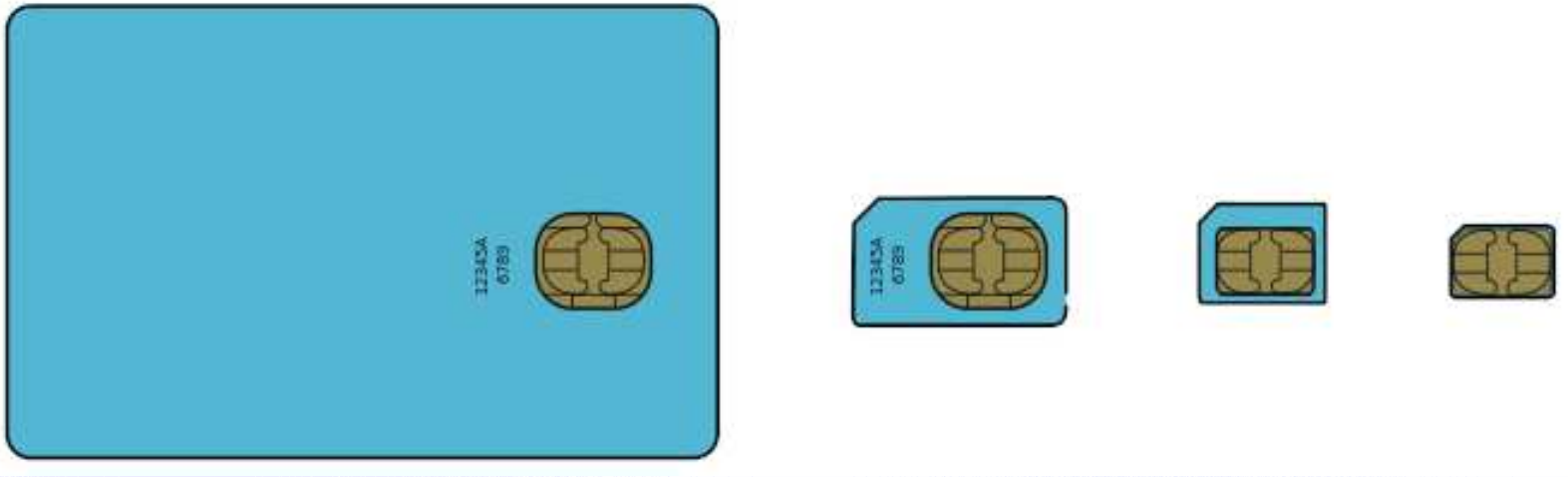
Struktura sieci GSM



https://en.wikipedia.org/wiki/GSM

GSM SIM

SIM card format	Year	Standard reference	Length	Width	Thickness
Full-size (1FF)	1991	ISO/IEC 7810:2003, ID-1	85.6 mm	53.98 mm	0.76 mm
Mini-SIM (2FF)	1996	ISO/IEC 7810:2003, ID-000	25 mm	15 mm	0.76 mm
Micro-SIM (3FF)	2003	ETSI TS 102 221 V9.0.0, Mini-UICC	15 mm	12 mm	0.76 mm
Nano-SIM (4FF)	2012	ETSI TS 102 221 V11.0.0	12.3 mm	8.8 mm	0.67 mm
Embedded-SIM (eSIM)	2010	ETSI TS 102.671 V9.0.0	6 mm	5 mm	<0.65 mm



https://en.wikipedia.org/wiki/SIM_card

GSM - pasma

GSM band	f MHz	Uplink MHz mobile to base	Downlink MHz base to mobile	Channel numbers	Equivalent LTE band
T-GSM-380	380	380.2 – 389.8	390.2 – 399.8	dynamic	None
T-GSM-410	410	410.2 – 419.8	420.2 – 429.8	dynamic	None
GSM-450	450	450.6 – 457.6	460.6 – 467.6	259–293	31
GSM-480	480	479.0 – 486.0	489.0 – 496.0	306–340	None
GSM-710	710	698.2 – 716.2	728.2 – 746.2	dynamic	12
GSM-750	750	777.2 – 792.2	747.2 – 762.2	438–511	None
T-GSM-810	810	806.2 – 821.2	851.2 – 866.2	dynamic	27
GSM-850	850	824.2 – 848.8	869.2 – 893.8	128–251	5
P-GSM-900	900	890.0 – 915.0	935.0 – 960.0	1–124	8 (subset)
E-GSM-900	900	880.0 – 915.0	925.0 – 960.0	0–124, 975–1023	8
R-GSM-900	900	876.0 – 915.0	921.0 – 960.0	0–124, 955–1023	?
T-GSM-900	900	870.4 – 876.0	915.4 – 921.0	dynamic	None
DCS-1800	1800	1710.2 – 1784.8	1805.2 – 1879.8	512–885	3
PCS-1900	1900	1850.2 – 1909.8	1930.2 – 1989.8	512–810	2

GSM - szybkosci

Mb/s	Theoretical Maximum Network Speeds		Typical Real World Network Speeds	
Network Type	Download Speed	Upload Speed	Download Speed	Upload Speed
3G	7.2	2	3	0.4
3G HSPA+	42	22	6	3
4G LTE	150	50	20	10
4G LTE-Advanced	300	150	42	25
5G	10000+	1000	200	100

Porównanie technologii

Technology	Distance	Speed range		Remarks
Ethernet	100 m	100 Mb/s	1 Gb/s	Expensive cabling
PLC	to nearest transformer	14 Mb/s	1300 Mb/s	Transmission range not limited to single house
WiFi	50 m	54 Mb/s	40 Gb/s	Transmission bands can be crouded
Bluetooth	10 m	2 Mb/s	50 Mb/s	Small range
Z-Wave	30 m	9.4 kb/s	200 kb/s	Slow
ZigBee	100 m	40 kb/s	250 kb/s	Slow. Transmission bands can be crouded
GSM	global	300 Mb/s	10 Gb/s	Expensive subscription

BACnet

- Building Automation and Control Network.
- 1987 - start of work
- 1995 ASHARE/ANSI standard nr 135
- 2003 - ISO 16484-5 standard
- Services
  - Who-Is
  - I-Am
  - Who-Has
  - I-Have
  - Read-Property
  - Write-Property
- Data link
  - ArcNet
  - Ethernet
  - BACnet/IP,
  - BACnet/IPv6
  - BACnetMSTP
  - Point to point over RS232
  - Token passing over RS485
  - ZigBee
  - LonTalk
- 60 object types like:
  - Analog Input
  - Analog Output
  - Analog Value
  - Binary Input
  - Binary Lighting Output
  - BitString Value
  - Calendar
  - CharacterString Value
  - Date Value
  - Group
  - Integer Value
  - ...

Modbus

- Modbus is a data communication protocol
- 1979 - first publication by Modicon (now Schneider Electric)
- 2004 - Modbus Organization
- Open and royalty free.
- Uses RS485 or Ethernet wiring.
- On RS485 there can be only one master.
- Gateways to ISM radio band, SMS and GPRS.
- Functions:
  - Read Discrete Inputs
  - Read Coils
  - Write Single Coil
  - Write Multiple Coils
  - Read Input Registers
  - Read Multiple Holding Registers
  - Write Single Holding Register
  - Write Multiple Holding Registers
  - Read/Write Multiple Registers
  - Mask Write Register
  - Read FIFO Queue
  - Read File Record
  - Write File Record
  - Read Exception Status
  - Diagnostic
  - Get Com Event Counter
  - Get Com Event Log
  - Report Slave ID
  - Read Device Identification
  - Encapsulated Interface Transport

CANbus

- CANbus - Controller Area Network
- 1983 - early developement in Bosh GmbH
- 1986 - official publication
- 1991 - first application in Mercedes Benz W140
- 1993 - ISO standard 11898-2
- Multimaster serial bus
- Twisted pair cabling
- Speed 1..5Mb/s ISO 11898-2; 125 kb/s ISO 11898-3

- Many upper layer protocols like:
  - CANopen
  - IEC 61375-3-3
  - DeviceNet
  - RV-C
  - SafetyBUS p
  - UAVCAN
  - CSP
  - VSCP
  - ...

Powtórzenie

- Jakie technologie sieciowe moga być zastosowane do połaczenia urządzeń automatyki domowe?
- Jakie sieci bezprzewodowe sa w tym celu stosowane?
- Jakie są wady i zalety tych rozwiazań?
- Do czego moze sie przydac siec GSM w automatyce domowej?

Pytania?