ZigBee™ & Co.

New Short Range Wireless Networks

Presenting Companies / Organisations

and:

Danfoss (DK)

ARS Software GmbH

Weinzierl Engineering GmbH

FH-Bochum

Outline

- Wireless Networks at a Glance
- Short Range Wireless Networks
- IEEE 802.15.4 and ZigBee
- Potential Application in a Parking Garage

Pro's and Con's of Wireless Networks

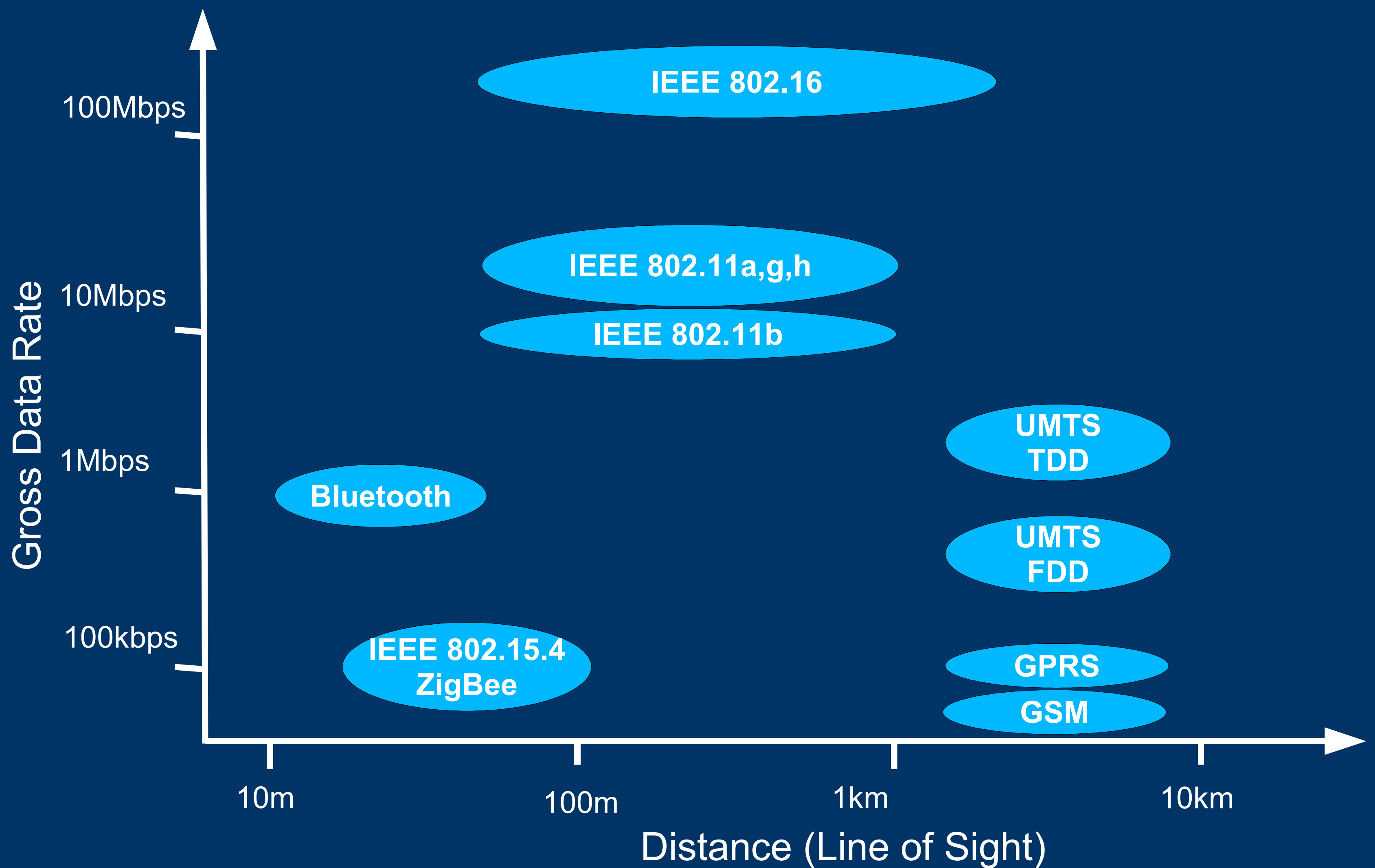
- Flexibility
- Portability
- Mobility
- Ad-Hoc Networking
- Mesh Networking

- Cost (per kbps)
- Range
- Persistency
- Coexistence
- Security

Classification of Networks

Wired networks		Wireless Networks	
PAN	not yet covered	WPAN	Bluetooth™ (IEEE 802.15.1), IEEE 802.15.4 & ZigBee™, proprietary, (soon: IEEE 802.15.3 UWB, Wireless USB)
LAN	IEEE 802.3 (Ethernet)	WLAN	IEEE 802.11 (WiFi™)
MAN	IEEE 802.3, FDDI	WMAN	IEEE 802.16 (WiMAX), proprietary
WAN	IEEE 802.3, X.25, ATM	WWAN	GSM, GPRS, UMTS

Wireless Standards



Evolution of Short Range Wireless Networks

Past → Present → Future

- MHz frequency range (40, 433, 868 MHz)
- proprietary systems
- point-to-point or star topologies
- permanently centralised systems
- unidirectional systems

- GHz frequency range (2.4, 5, 24, 50 GHz)
- standardised / open systems
- ad-hoc, mesh and multi-hop networks
- autarkic distributed systems (“eGrain”)
- bidirectional systems

Why Standardisation, why not?

- economies of scale for mass production
- reduced dependence from one supplier
- increased number of market participants
- chances for market newcomers & smaller companies
- chance of interoperability - customer's benefit

- longer time to market
- political discussions
- increased complexity, cost, power consumption

Overview of current Short Range Wireless Networks

		Blue-tooth	ZigBee	z-wave	Ember Net	nanoNET	Konnex-RF	IrDA
Markets	Home Automation		x	x	x	x	x	
	Industrial Automation		x		x	x		x
	Building Automation		x		x	x	x	
	Consumer Electronics	x						x
Topology	Point-to-Point	x	x	x	x	x	x	x
	Star	x	x	x	x		x	
	Multi-Hop / Mesh		x	x	x			
	Complexity (# of Nodes)	7	~ 500	~ 200	~ 500	-2	~ 15	2
Optimisa-tion	Power Consumption		x	x	x	x		
	Interoperability	x					x	
	Comfort	x						x
# of Suppliers	Hardware	many	some	one	one	one	few	many
	Software	many	few	few	one	one	few	many
	System Integrator	many	many	some	one	one	few	many

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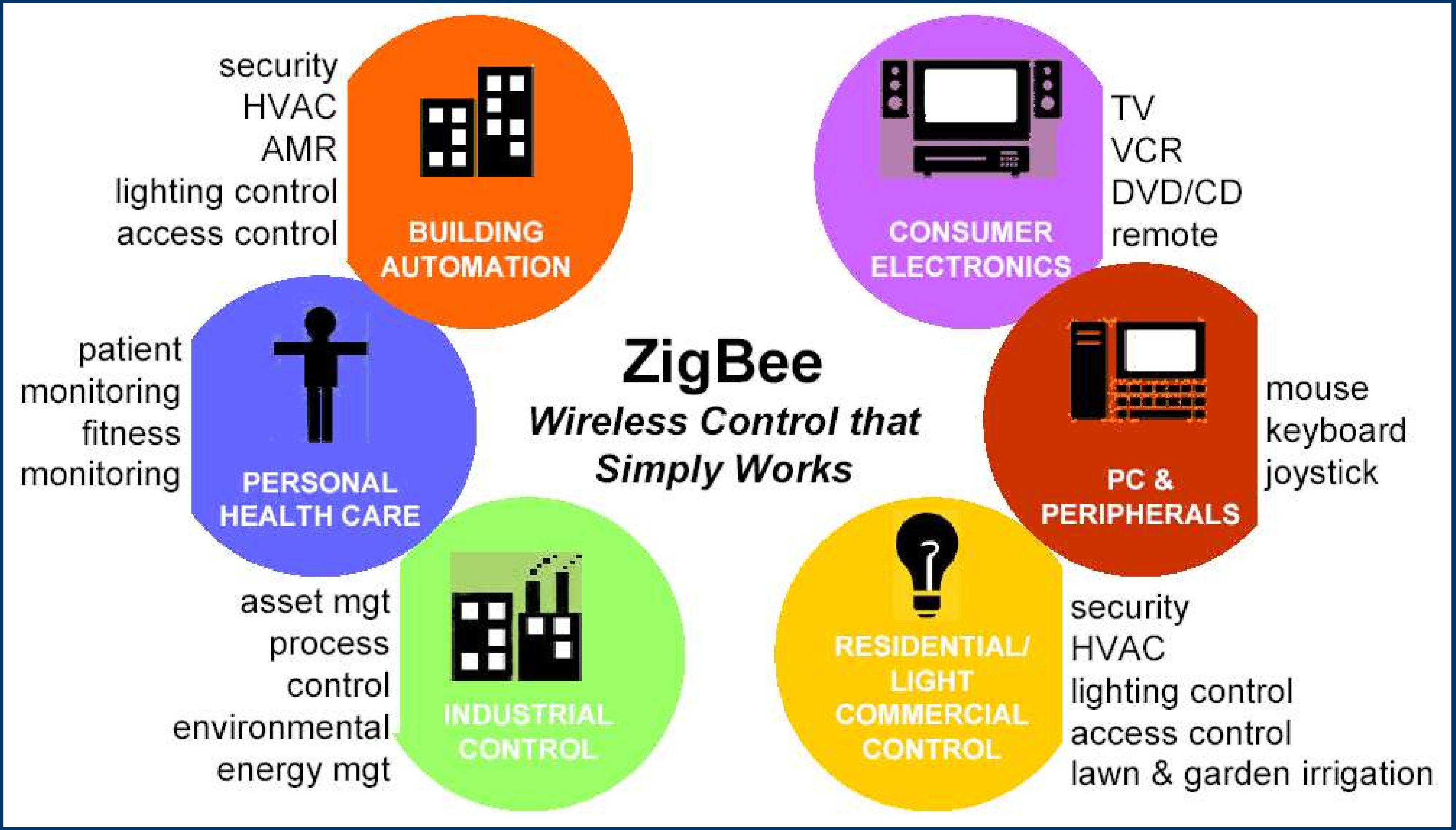
Goals of the ZigBee™-Alliance

ZigBee™ Alliance
Wireless Control That Simply Works

- create a specification for mesh, peer-to-peer, and cluster tree networks
- provide a cost-effective, standards-based wireless networking solution supporting low data rates, low power consumption, security and reliability
- define interoperable application profiles

ZigBee™ Applications



ZigBee Alliance, www.zigbee.org

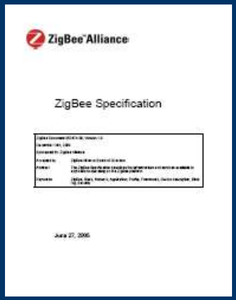
ZigBee™-Alliance

- levels of memberships:
  - promoters ->
  - participants
  - adopters
- now more than 150 members
- History:

1998	"HomeRF" working group around Philips
Aug 2001	named as "ZigBee"
End of 2002	foundation of the ZigBee-Alliance
Oct 2003	ratification of IEEE 802.15.4
Dec 2004	ratification of ZigBee Standard V1.0, available to the public since Feb 2005, V1.1, V1.2 extensions under discussion

IEEE 802.15.4 & ZigBee™ OSI-Model

APPLICATION / PROFILES	user defined or ZigBee-profile
APPLICATION FRAMEWORK	ZigBee™
NETWORK / SECURITY LAYERS	ZigBee™
MEDIUM ACCESS CONTROL (MAC) LAYER	IEEE 802.15.4 (WPAN Low Rate)
PHYSICAL (PHY) LAYER	IEEE 802.15.4 (WPAN Low Rate)



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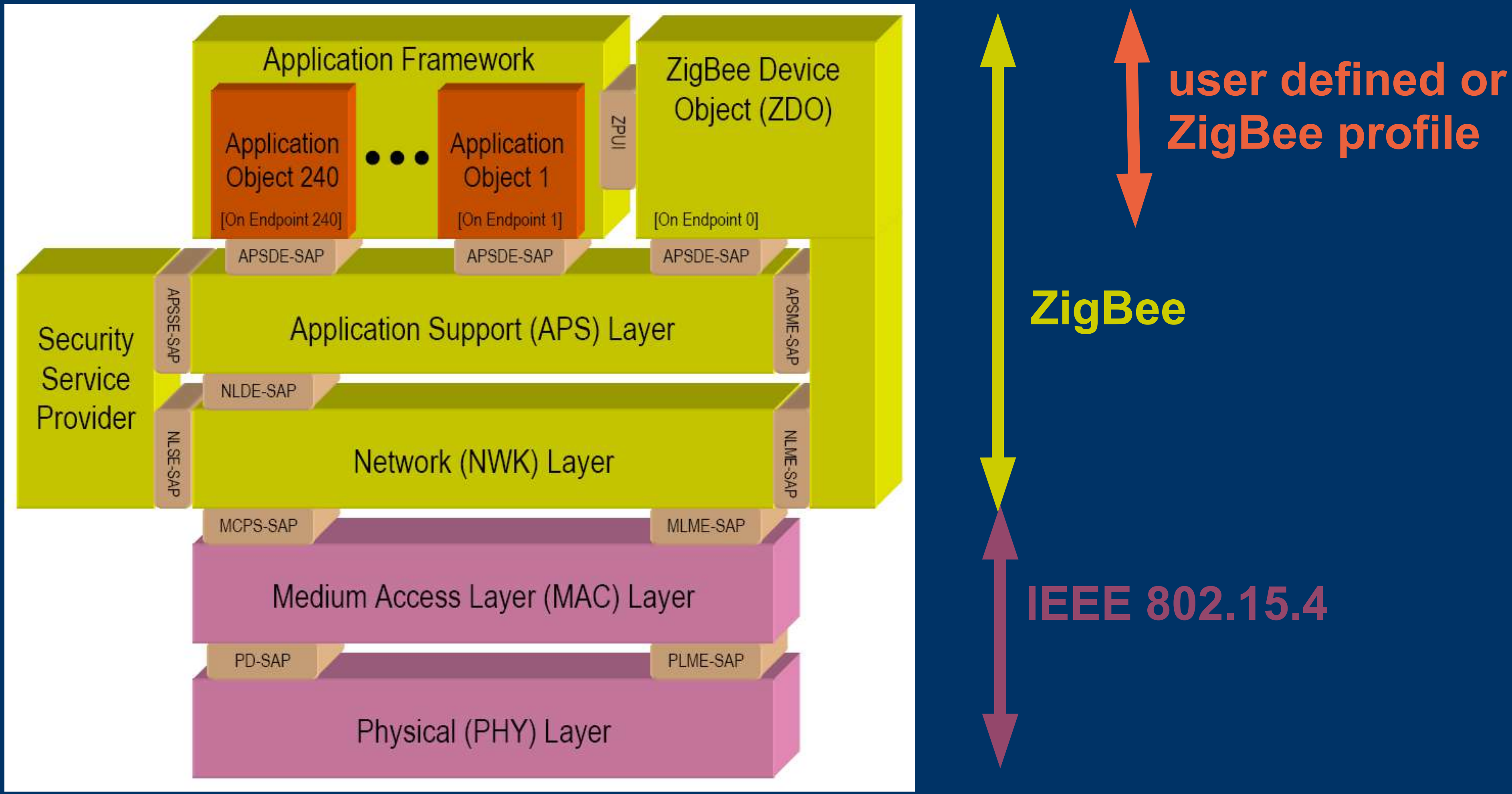
IEEE 802.15.4 & ZigBee™ Protocol Stack



ZigBee Alliance, www.zigbee.org

IEEE 802.15.4 Physical Layer

APL/PROF
APL FRWRK
NWK / SEC
MAC- LAYER
PHY-LAYER

PHY	Frequency Band MHz	Region	Channel #	Spreading Parameters		Data Parameters		
				Chip Rate kchip/s	Modulation	Data Rate kbps	Symbol Rate ksymbol/s	Symbols
868/915 MHz	868-870	Europe	0	300	BPSK	20	20	binary
	902-925	America	1-10	600	BPSK	40	40	binary
2.4 GHz	2400-2483.5	world-wide	11-26	2000	O-QPSK	250	62.5	16-ary orthogonal

- 2 different PHY layers at license free frequency bands
- radio design optimised for low costs:
  - few analogue stages, digital whenever possible
  - modulation allows non-linear output stages
- Direct Sequence Spread Spectrum (DSSS)
- transmit power at least -3 dBm
- receiver sensitivity -85 dBm or better (@1% PER)
- range 30..70..(100)m

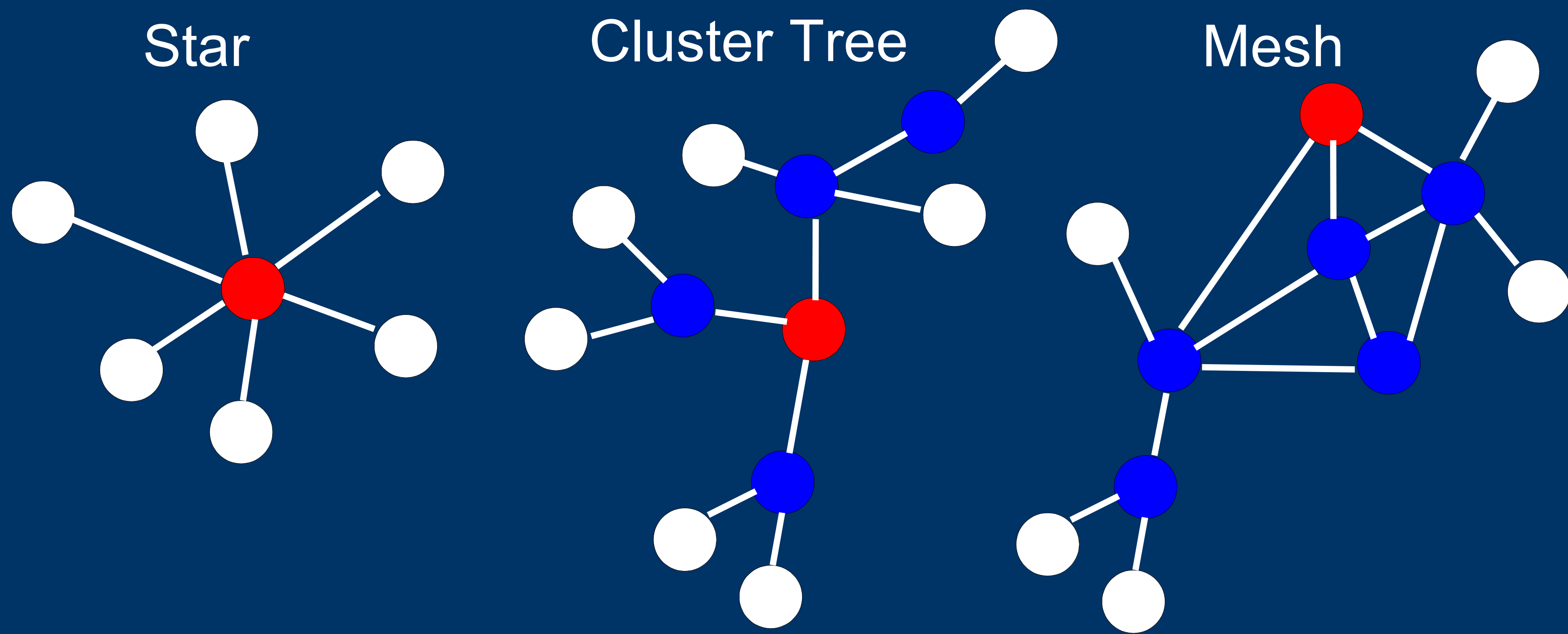
IEEE 802.15.4
Medium Access Control Layer

APL/PROF
APL FRWRK
NWK / SEC
MAC- LAYER
PHY-LAYER

- two "Physical Device Types": - Full Function Device (FFD),
  - Reduced Function Device (RFD)
- power optimisations:
  - minimized time to radio, sleeping nodes, low duty-cycles resulting in very low average power (aiming years of battery lifetime)
- channel access options:
  - non-beaconing Carrier Sense Multiple Access with Collision Avoidance CSMA/CA ("listen before talk")
    (some devices constantly active while others almost always asleep)
  - beacon-enabled CSMA/CA
    (nodes synchronise to particular times to hear and talk, at least all 250sec)
  - optional superframes with reserved time slots for time-critical data

ZigBee™ Network Layer - Topologies

APL/PROF
APL FRWRK
NWK / SEC
MAC- LAYER
PHY-LAYER



"Logical Device Types":

- ZigBee Coordinator (FFD)
- ZigBee Router (FFD)
- ZigBee End Device (RFD or FFD)

ZigBee™ Network Layer - Routing

APL/PROF
APL FRWRK
NWK / SEC
MAC- LAYER
PHY-LAYER

- Star Network
  - no multi-hop network
  - 65535 ZigBee end devices in theory, under 500 due to limited resources in reality
- Cluster Tree Network
  - beaconing multi-hop network
  - synchronised nodes allowing sleeping ZigBee routers and end devices (low power)
  - static hierarchical routing
- Mesh Network
  - non-beaconing multi-hop network
  - radio receivers of ZigBee coordinator and routers must be active all times (high power)
  - dynamic table-driven routing

ZigBee™ Security

APL/PROF
APL FRWRK
NWK / SEC
MAC- LAYER
PHY-LAYER

- concept of "Trust Center" (usually ZigBee coordinator)
- encryption: 128 bit AES (Advanced Encryption Standard)
- residential mode
  - trust center allows devices to join the network, but does not establish keys
  - no maintaining of keys with network devices, thus no periodically updating of keys
  - minimal memory cost in the trust center, does not scale with size of network
- commercial mode:
  - trust center establishes and maintains keys
  - allows for centralised control and update
  - memory cost in the trust center can scale with size of network

ZigBee™ Application Layer

APL/PROF
APL FRWRK
NWK / SEC
MAC- LAYER
PHY-LAYER

- tasks of the ZigBee application layer:
  - initialisation,
  - configuration,
  - binding (logical connection)
- ZigBee application objects
  - logical extensions of a single device (up to 240)
  - allows for multiple applications using one radio
- ZigBee application profiles
  - allow interoperability of devices from different vendors
  - first defined profile: home control lighting
  - still a lack of further profiles

Scalability of Standardisation

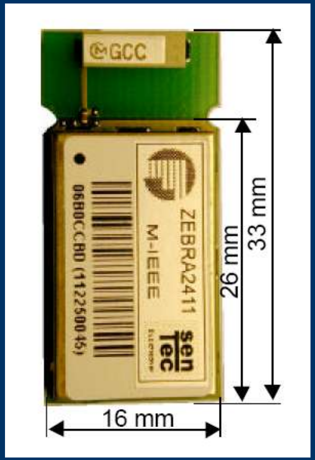
ZigBee incompatible platform	ZigBee network capable product	ZigBee certified product
NON-PUBLIC (PROPRIETARY) APPLICATION	NON-PUBLIC PROFILE / APPL.	ZIGBEE PUBLIC PROFILE
	ZIGBEE APPL. LAYERS	ZIGBEE APPL. LAYERS
	ZIGBEE NWK/ SEC LAYERS	ZIGBEE NWK/ SEC LAYERS
IEEE 802.15.4 MAC-LAYER	IEEE 802.15.4 MAC-LAYER	IEEE 802.15.4 MAC-LAYER
IEEE 802.15.4 PHY-LAYER	IEEE 802.15.4 PHY-LAYER	IEEE 802.15.4 PHY-LAYER

► modular structure of protocol stack allows scalable implementations

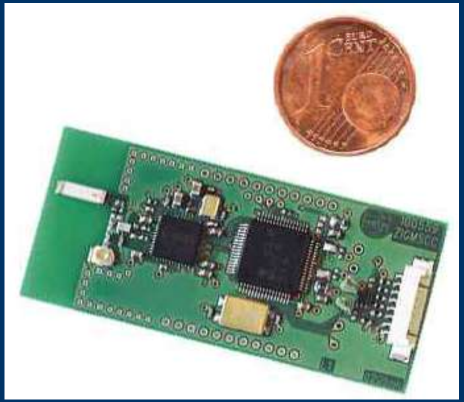
IEEE 802.15.4 & ZigBee™ System Design

- standard allows the use of small & cheap microcontrollers (8/16 bit... estimated RAM for MAC-layer: RFD 12kB to 16kB, FFD 16kB to 20kB)
- RF-chip solutions available from different vendors
- several wireless modules available
- (estimated cost of radio chip in very high volumes: $1.10)

ZigBee enabled board (ZEBRA), SenTec, Ilmenau



ZigBee prepared module, Livetec, Lörrach



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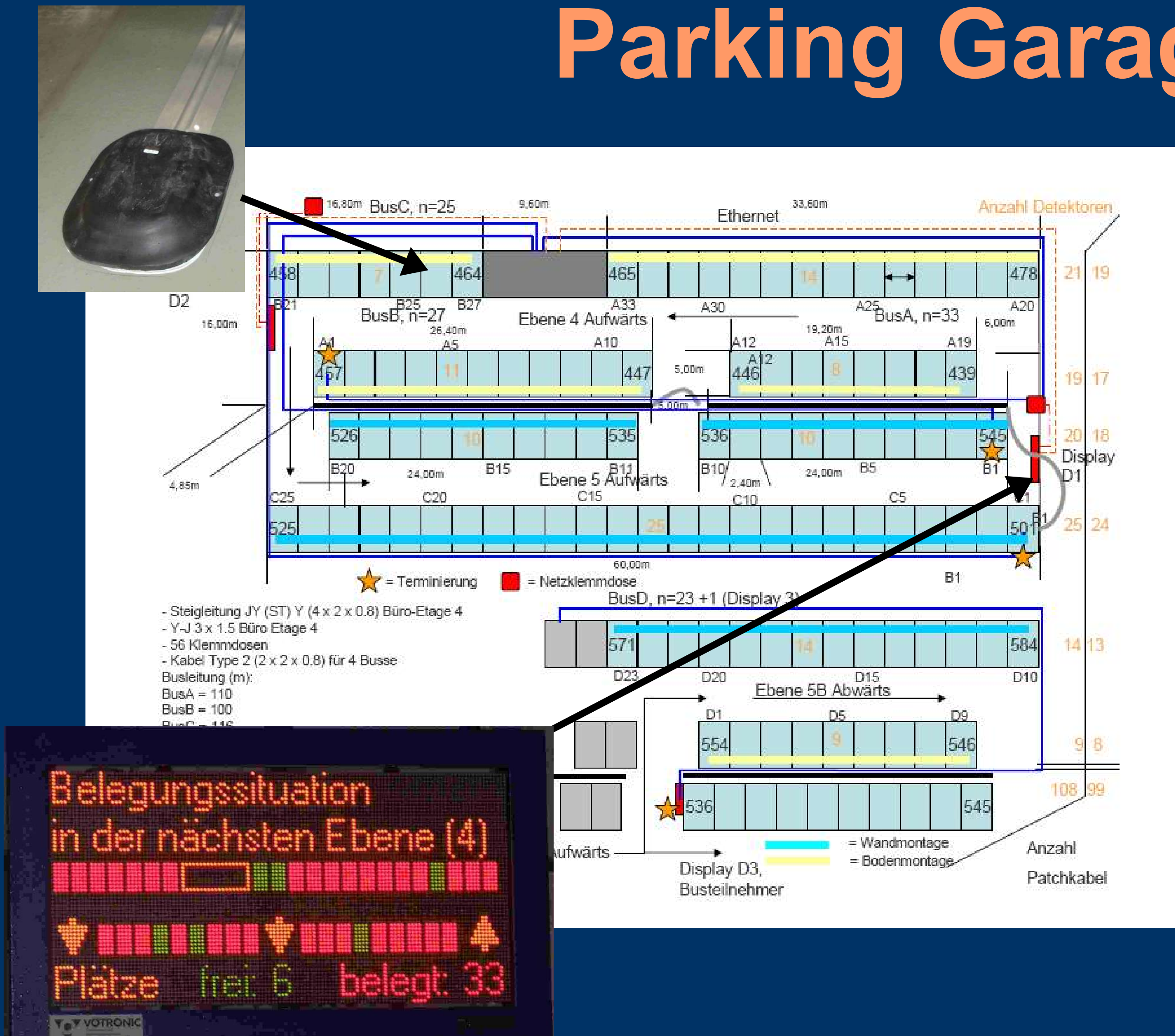
ZigBee™ today – Strengths and Weaknesses

- accepted standard
- HW & SW available
- several chip vendors
- several suppliers for wireless modules
- mesh/multi-hop networking
- possible interoperability

- relatively high complexity of stack
- lacks in
  - mesh/multi-hop networks
  - routing
  - TCP/IP support
  - interconnection to installation buses & PCs
- no dynamic channel selection
- just a few SW vendors

Potential Application in a Parking Garage



- 2 $^{1}/_{2}$ levels of Lampertshof parking garage
- installation of 108 magn. sensors to monitor occupied parking slots
- > 500m cable,
  > 300m cable channel,
  many cable connections,
  several working nights

Thank You!