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Evaluation of PLC using simulation and laboratory measurements

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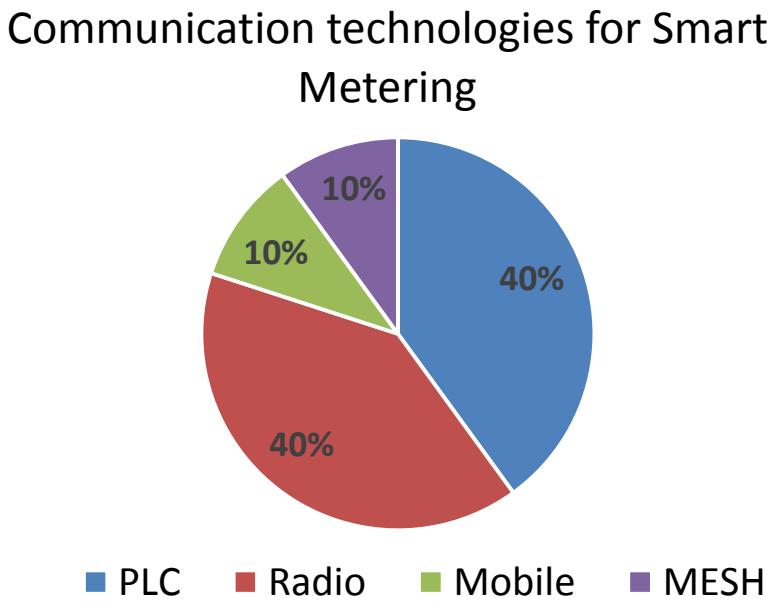
11th WorkShop on Power Line Communications

Goals

- Smart Grid – will exploit multiple types of communications technologies
- Smart Metering - best defined and most widespread subsystem concept of Smart Grid

- **Power grid – is not the same in any utility**
  - Architecture (MV x LV), material, evolution, circumstances, cable types

- **It is possible to use simulation tools for Smart Metering PLC network deployment?**
  - Are the results useful for utility?

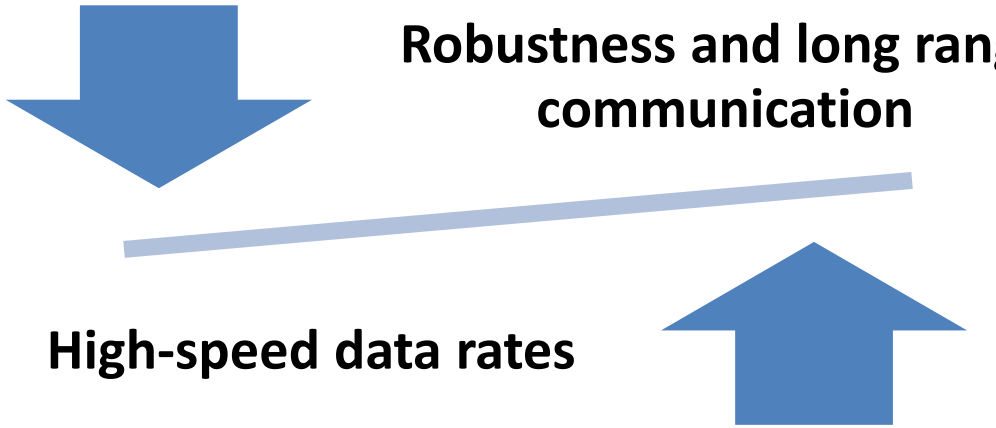


Smart Grid and PLC

- **BPL**
  - Throughput
- **HDR NB-PLC**
  - Throughput vs. robustness
- **NB-PLC**
  - Communication distance

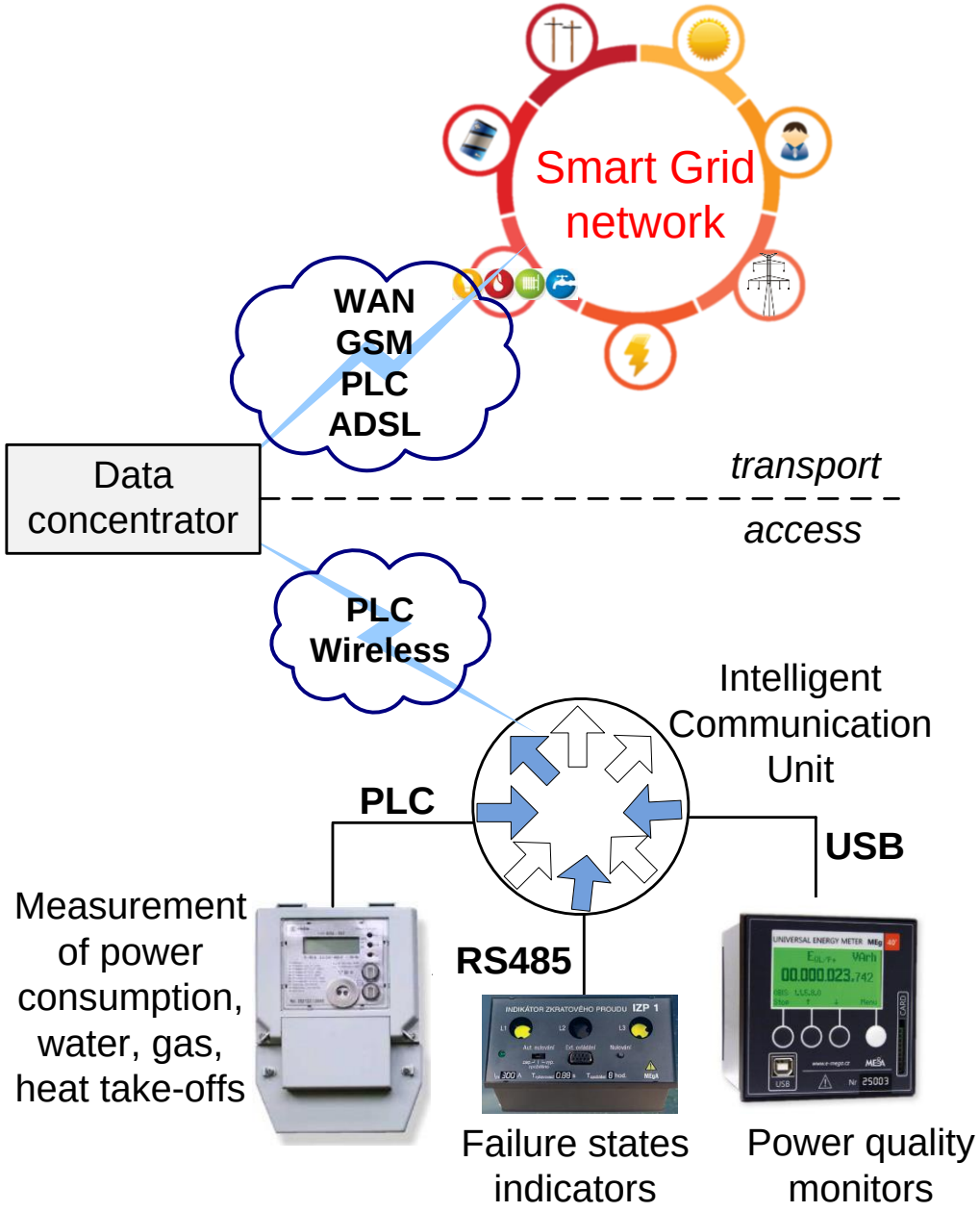
Application requirements

- Robustness and long range communication
- High-speed data rates



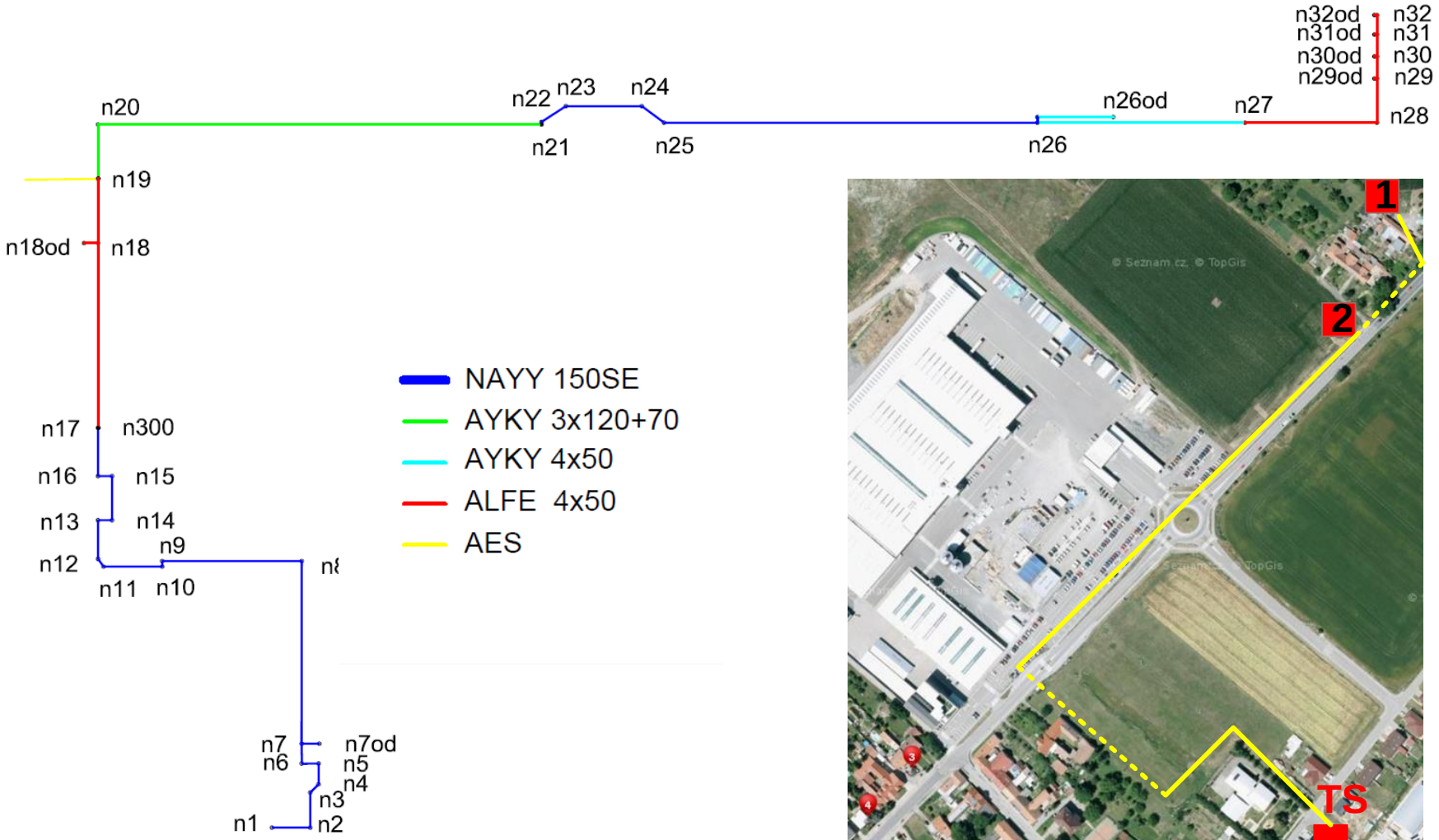
Outline

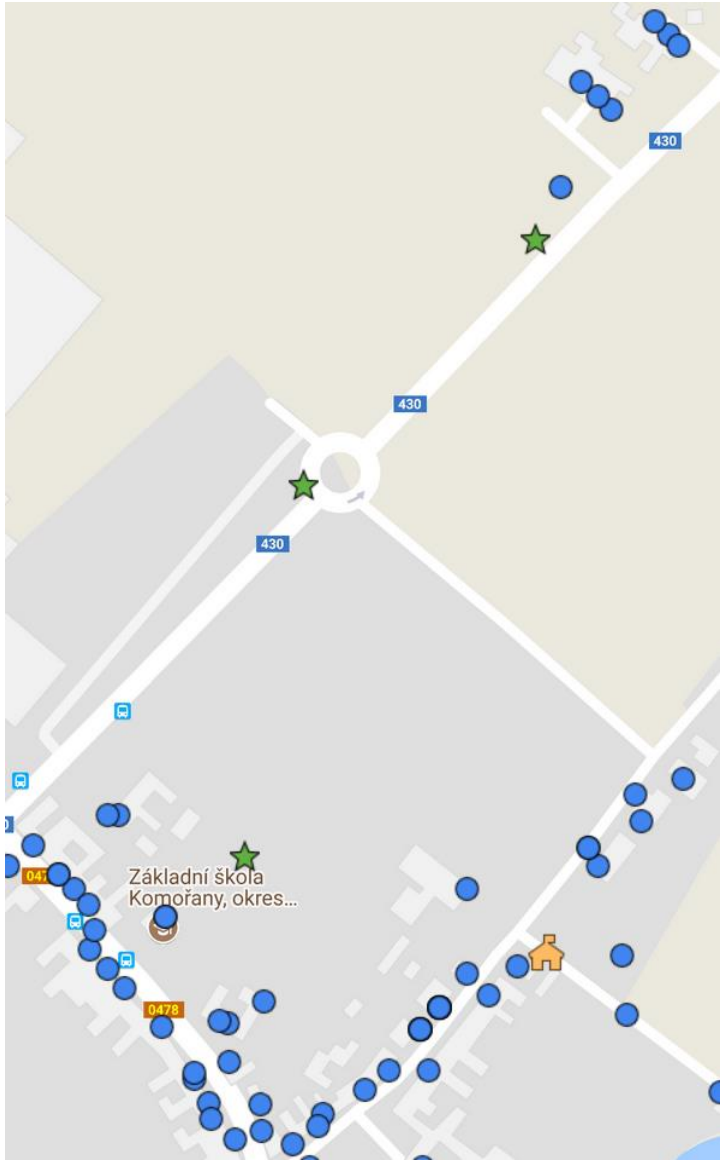
- **BPL for Smart Metering** (last mile)
  - Real topology
  - Classification of topologies - simulation
- **HDR NB-PLC for Smart Metering** (last mile)
  - Differences between modes
- **NB-PLC for Smart Metering** (last mile)
  - Communication distance
- **BPL on medium voltage line** (transport part)
  - max. communication distance, throughput



BPL for Smart Metering – real topology

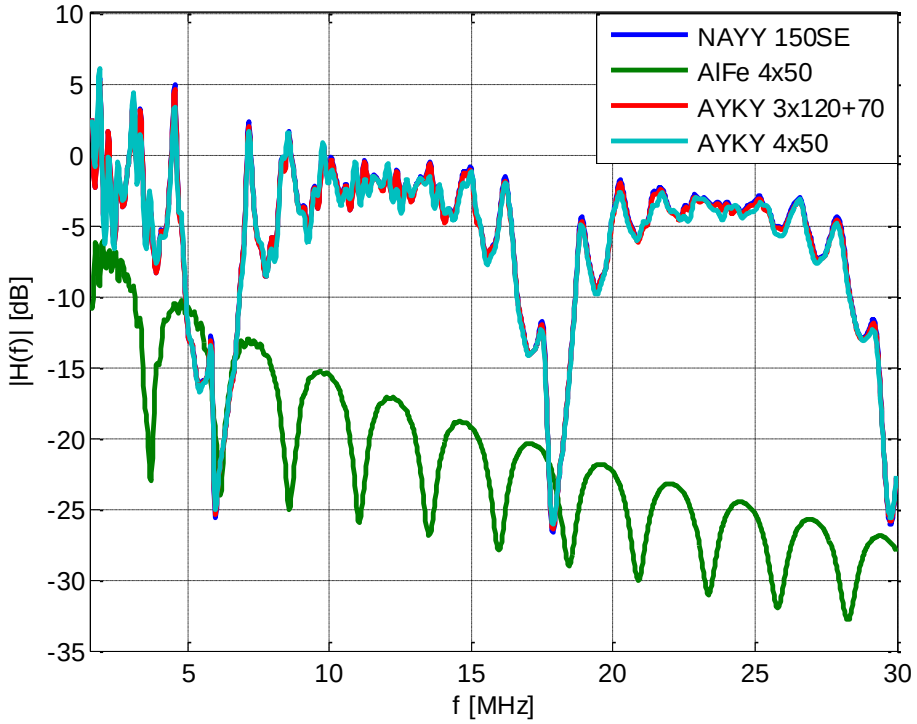
- cooperation with E.ON [1]
- implementation in the NS-3 PLC framework

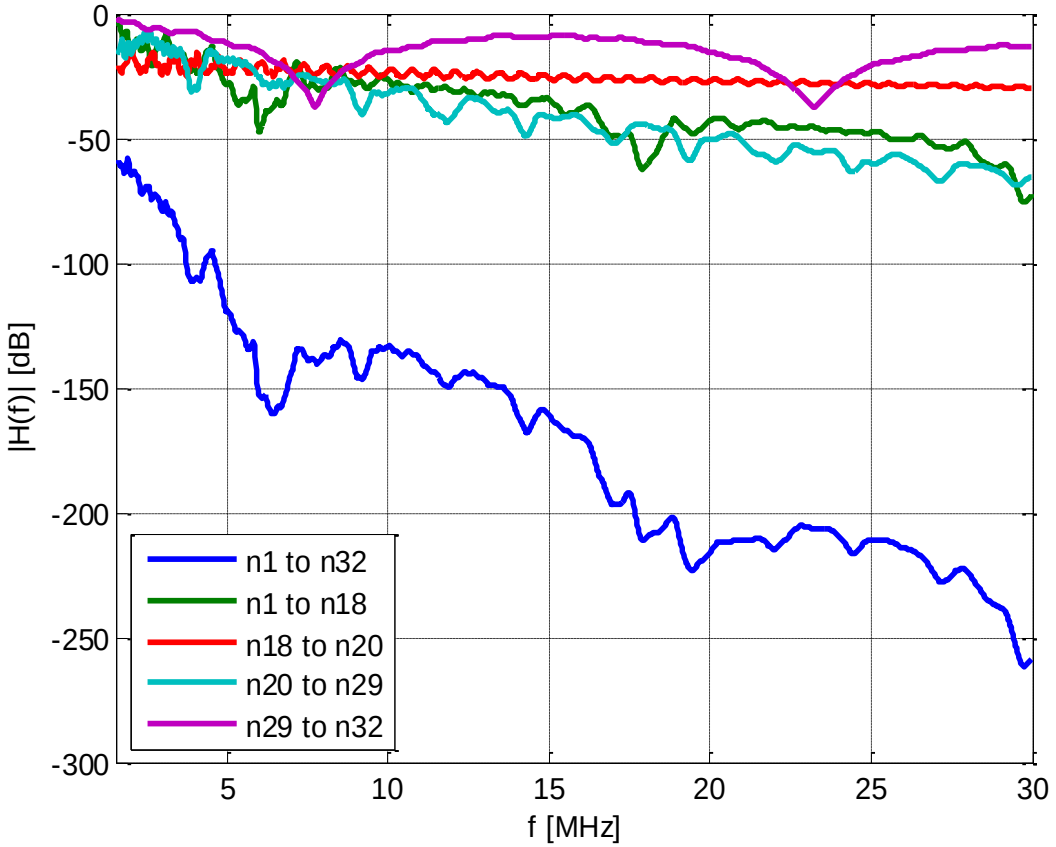




BPL for Smart Metering – real topology

- BPL maximum communication distance due to noise or distance without repeaters
- knowledge of the number and position of repeater (cooperation with E.ON [1])





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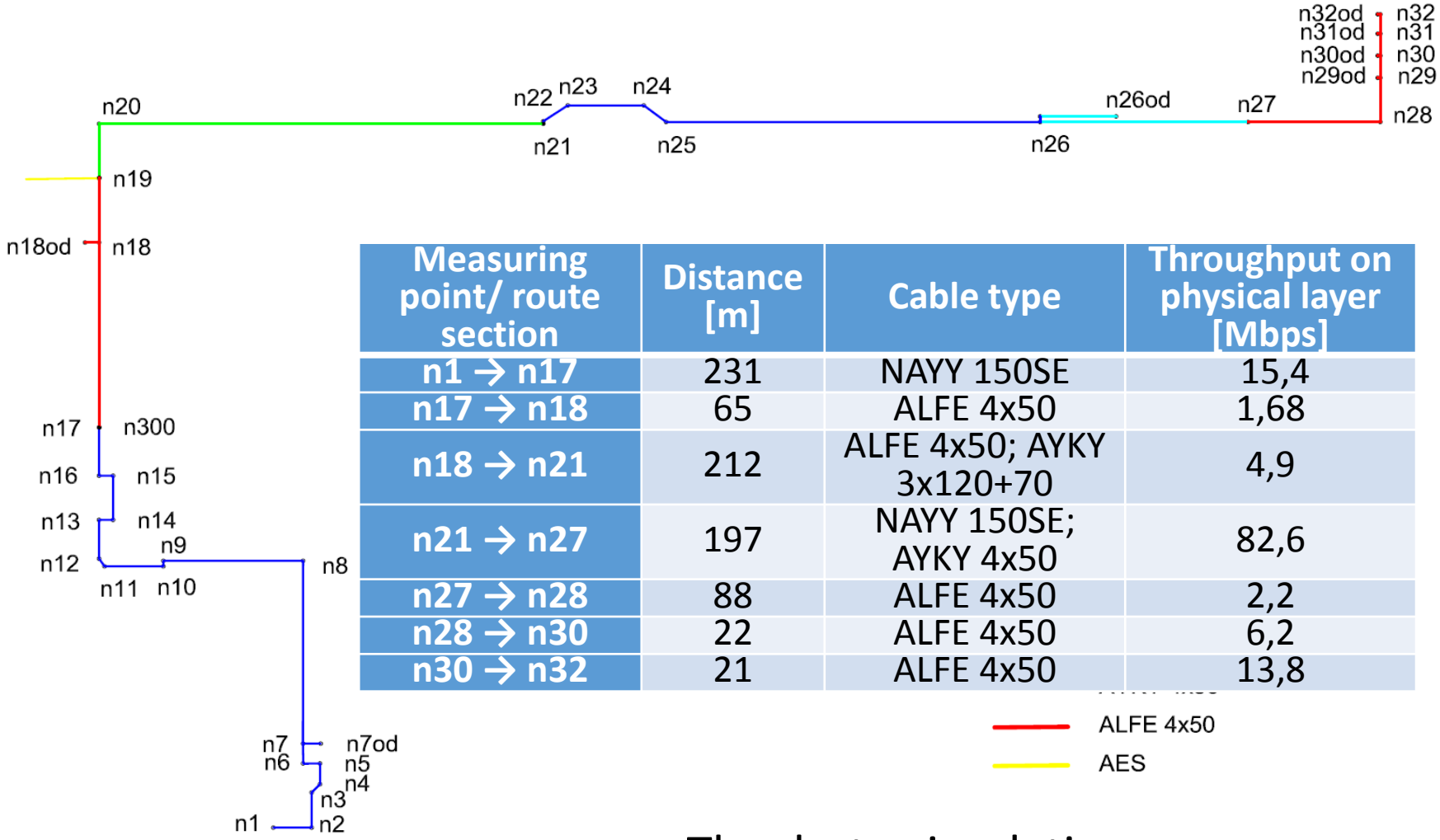
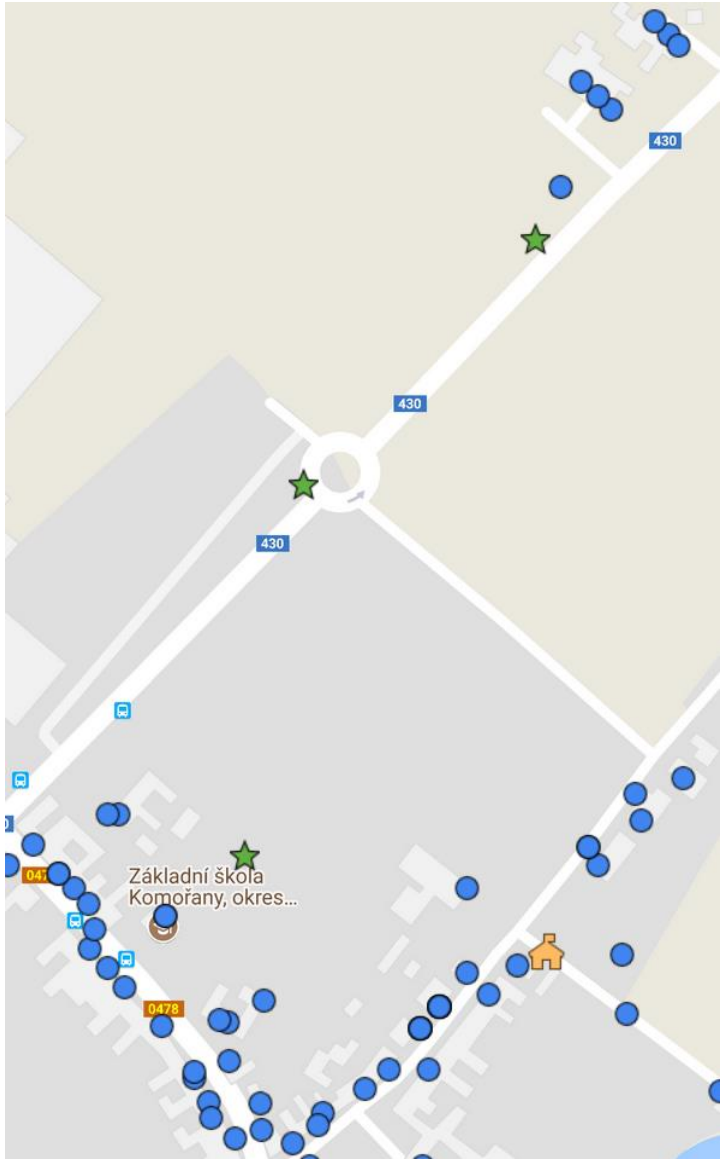
[1] MLÝNEK, P.; FUJDIAK, R.; ŠILHAVÝ, P.; MIŠUREC, J.; FRANEK, L.; ZAMPHIROPOLOS, J.; PAŘÍZEK, J. Role PLC v Smart Metering rollouts – porovnání a metodika hodnocení pilotních PLC realizací. In Sborník konference ČK CIRED 2015. 2015. s. 1-19. ISBN: 978-80-905014-4- 7.

BPL for Smart Metering – real topology simulation and measurement



Measuring point/ route section	Distance [m]	Cable type	Throughput on physical layer [Mbps]
n1 → n17	231	NAYY 150SE	15,4
n17 → n18	65	ALFE 4x50	1,68
n18 → n21	212	ALFE 4x50; AYKY 3x120+70	4,9
n21 → n27	197	NAYY 150SE; AYKY 4x50	82,6
n27 → n28	88	ALFE 4x50	2,2
n28 → n30	22	ALFE 4x50	6,2
n30 → n32	21	ALFE 4x50	13,8



Thanks to simulation:

- BPL signal repetition in the grid
- Throughput bottleneck

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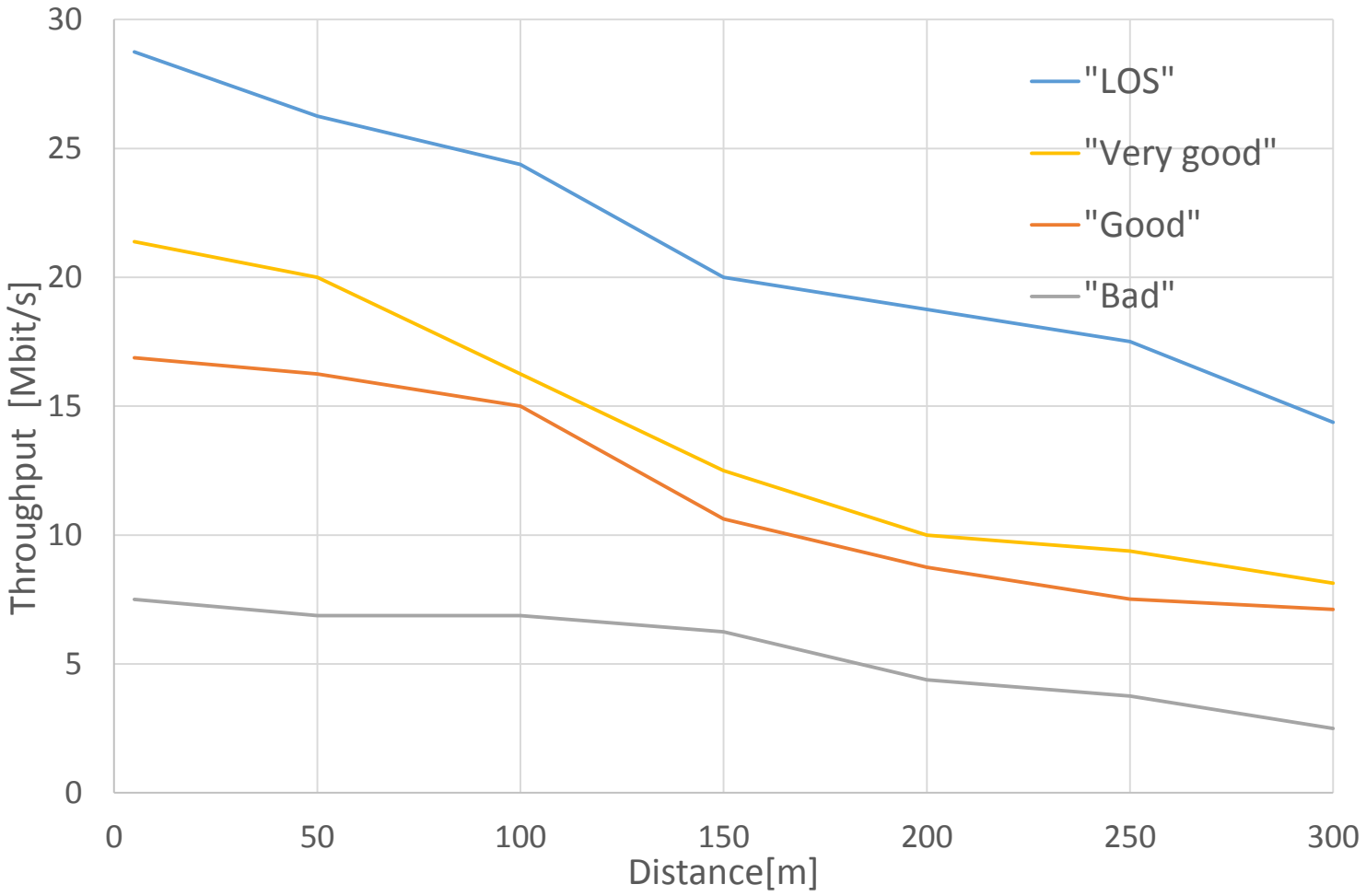
BPL for Smart Metering – Simulation

- „LOS“ channel – SNR = 36,5 dB
- „Very good“ channel – SNR = 26,28 dB
- „Good“ channel – SNR = 21,2 dB
- „Bad“ channel – SNR = 10,6 dB



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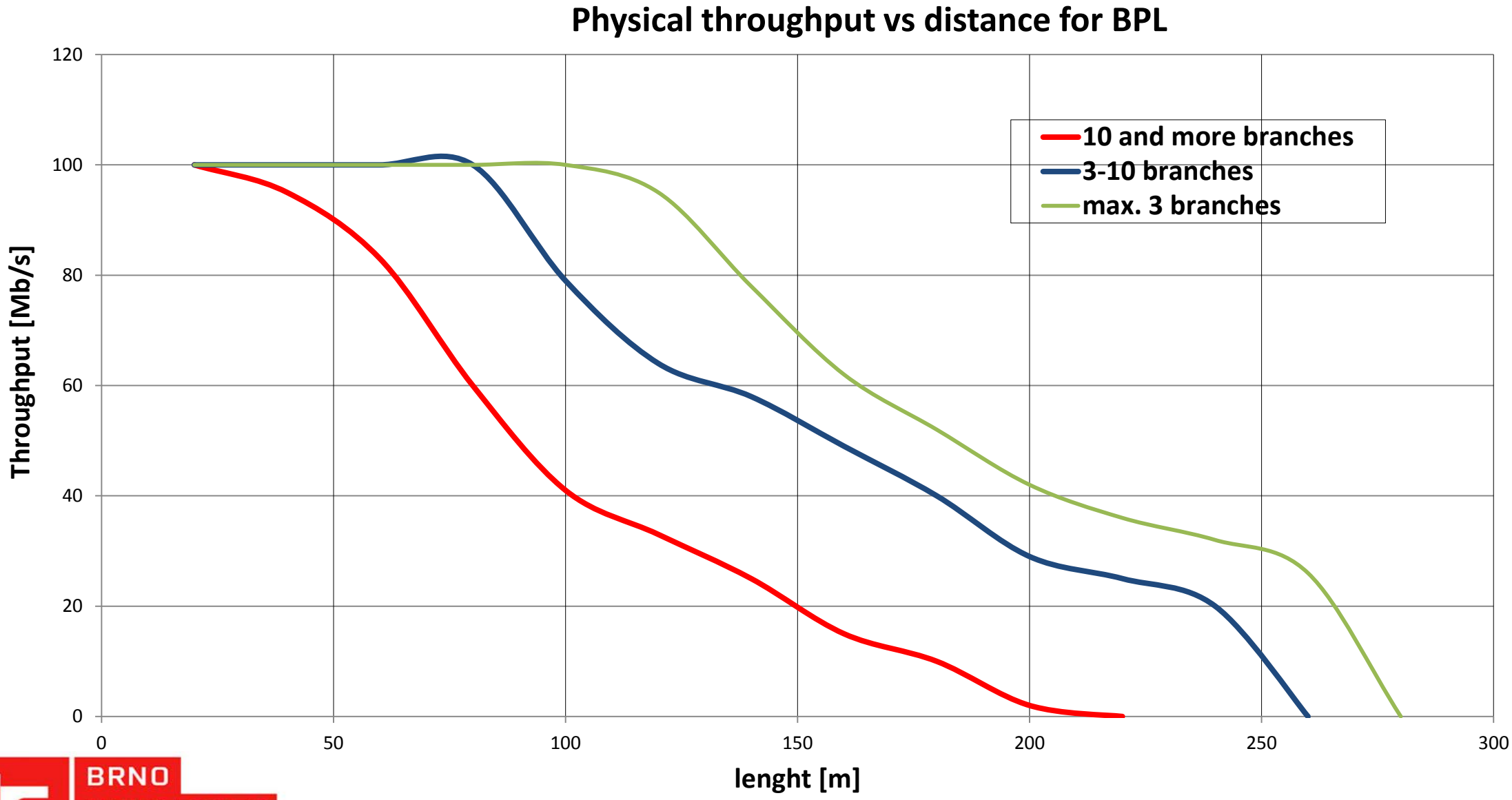
BPL for Smart Metering – Simulation



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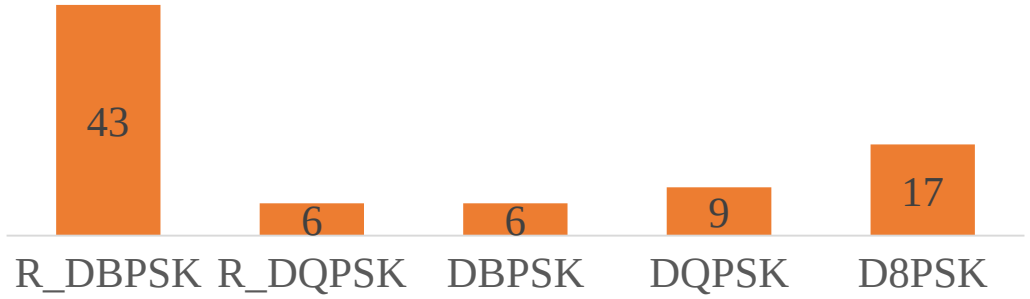
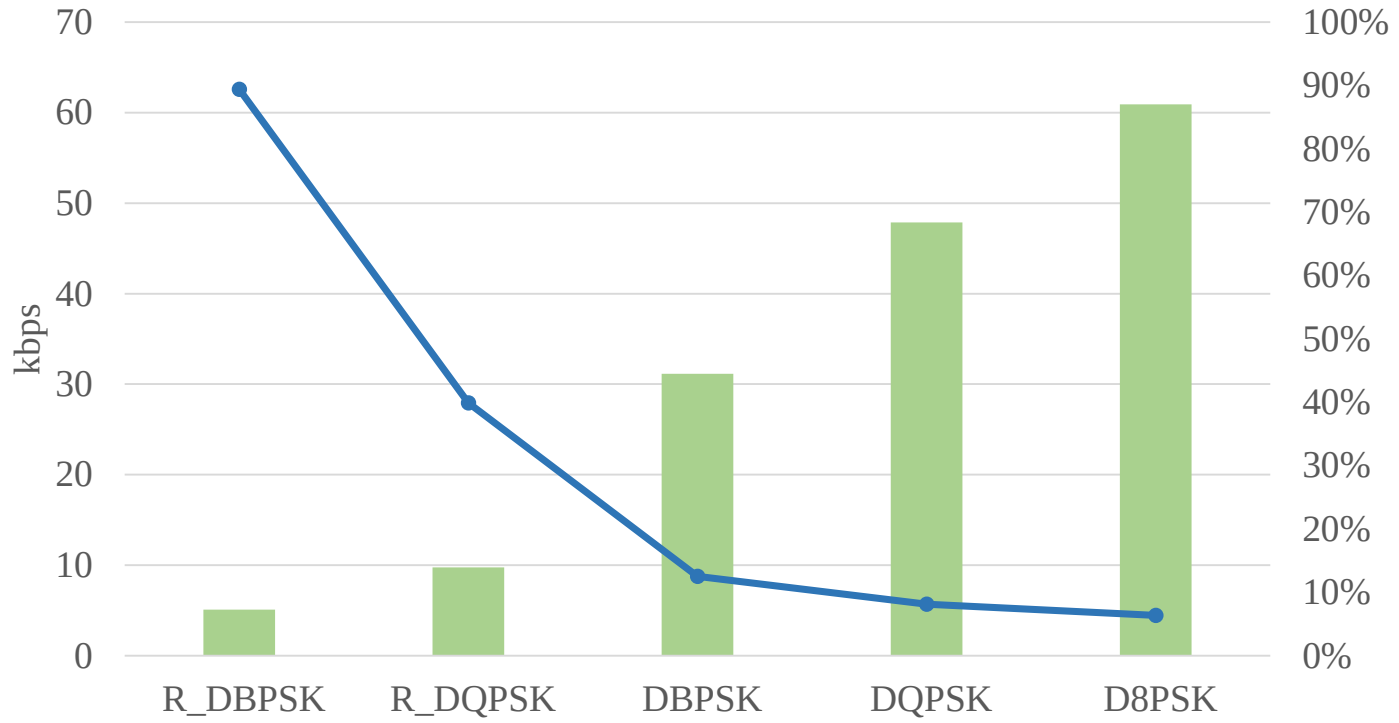
HDR NB-PLC for Smart Metering

- Real measurement between underground transformer substation and smart meter
- PRIME v1.4
- 400 m
- Without repeater
- SNR 3-5

Received frames with good payload (total 500)



Throughput for different modulation vs channel usage



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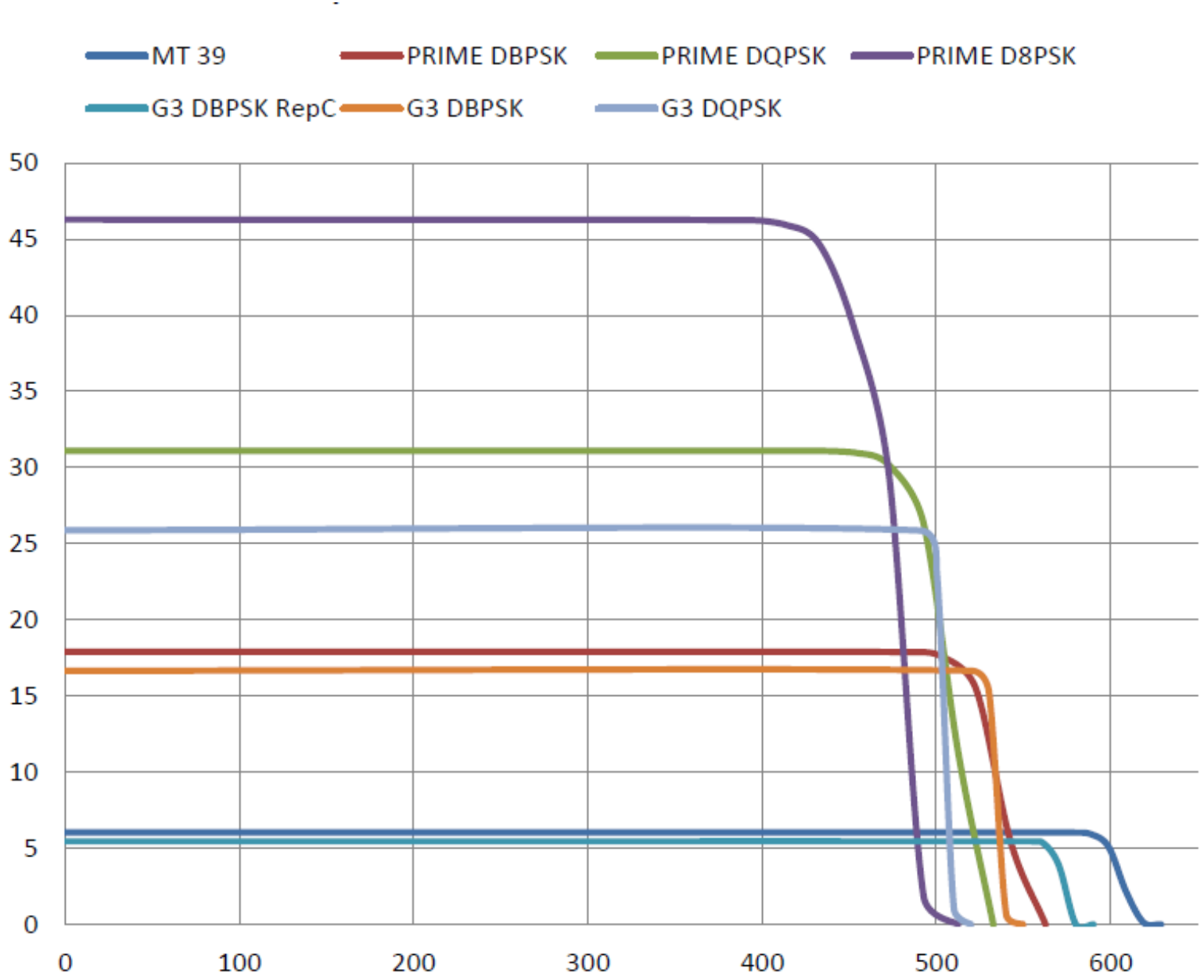
Simulation NB-PLC



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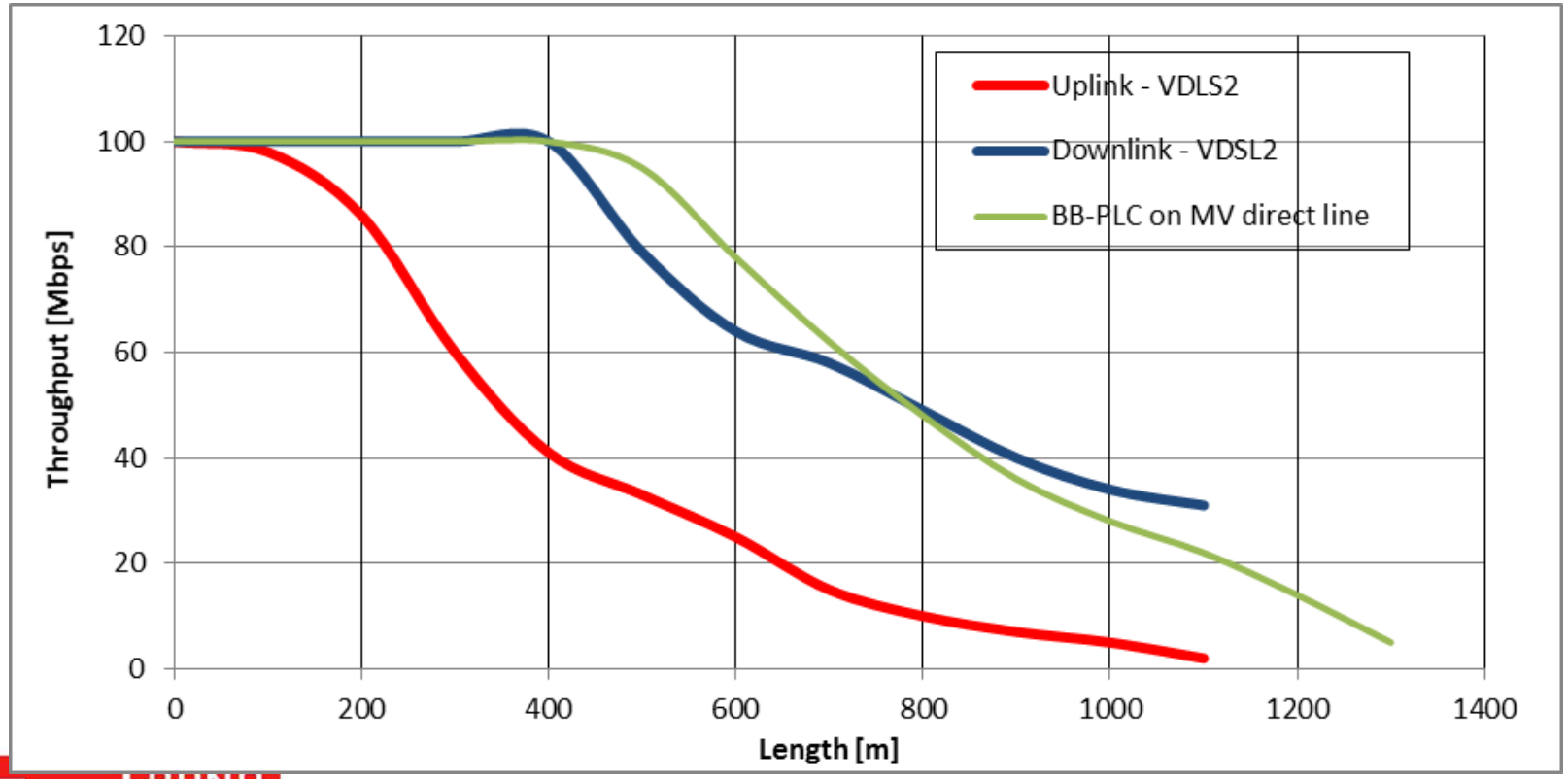
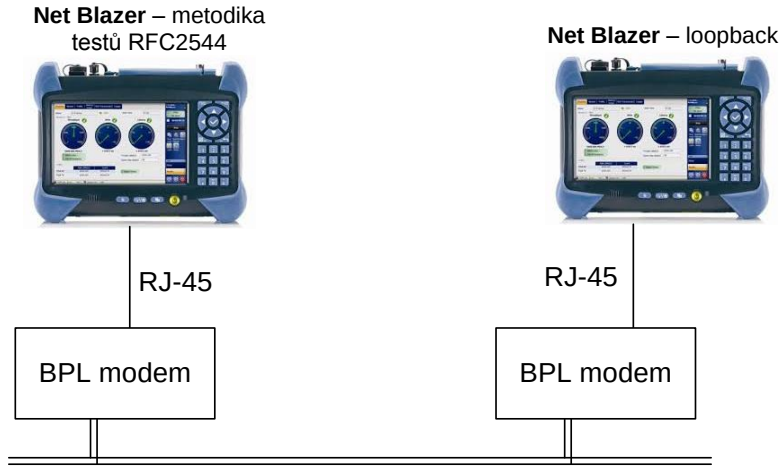
Measurement NB-PLC

Smart Meter	Distance[m]	Possibility of communication
1	820	No
2	704	Yes

Measurement and simulation of BPL on MV

- **Broadband PLC on underground medium voltage 6kV**
- Direct line of visibility 1150 m
- Power line distance 1942 m





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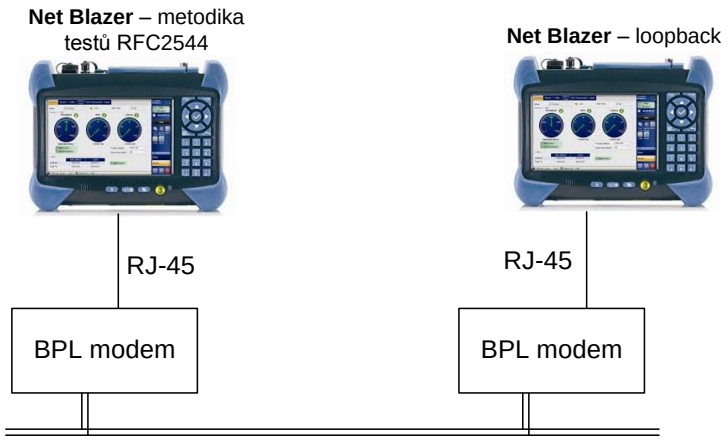
Measurement of BPL for MV in laboratory



	TCP Throughput				
	Window	Ideal L4 (Mbit/s)	Actual L4 (Mbit/s)	TCP Efficiency (%)	Buffer Delay (%)
L->R	33 KiB	93,9	29,5 Disabled	100,00	222,97
R->L	33 KiB	93,9	29,0 Disabled	100,00	229,30

Throughput (Mbit/s)	UDP					
	Layer					
	All		Ethernet		IP	
	L->R	R->L	L->R	R->L	L->R	R->L
64	28,2500		21,5238		15,4702	
512	74,3749		71,5789		69,0624	
1518	89,3749		88,2127		87,1667	

Conclusion

- **Simulation allows predicting PLC behavior**
- **Only different combination of different PLC technologies in the various grid segment**

Thank you for listening.

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