SMER ZA KOMUNIKACIONE TEHNOLOGIJE I OBRADU SIGNALA

Katedra za telekomunikacije i obradu signala

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Large-Scale Distributed Data Acquisition and Information Processing via 5G Mobile Cellular Networks

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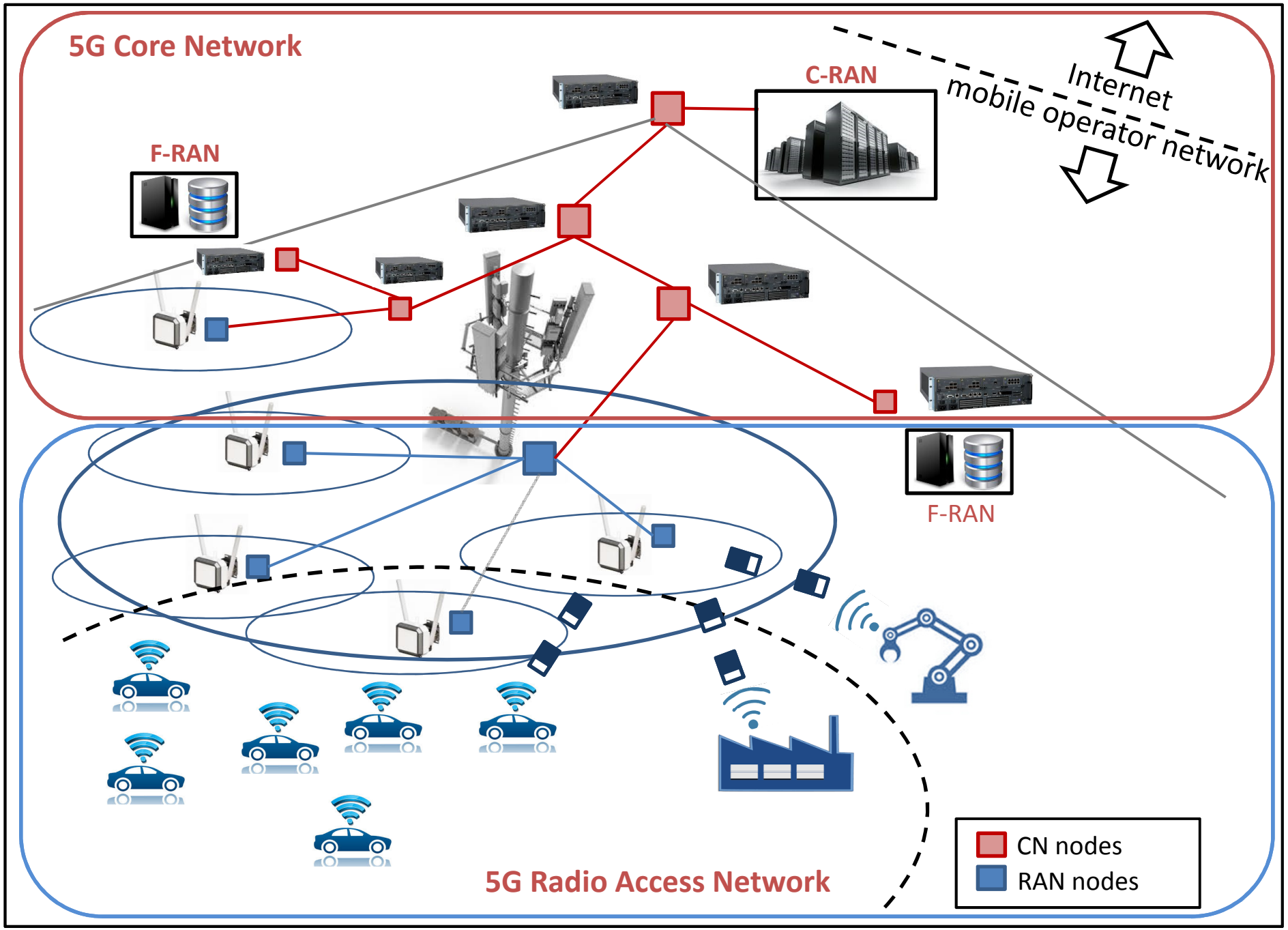
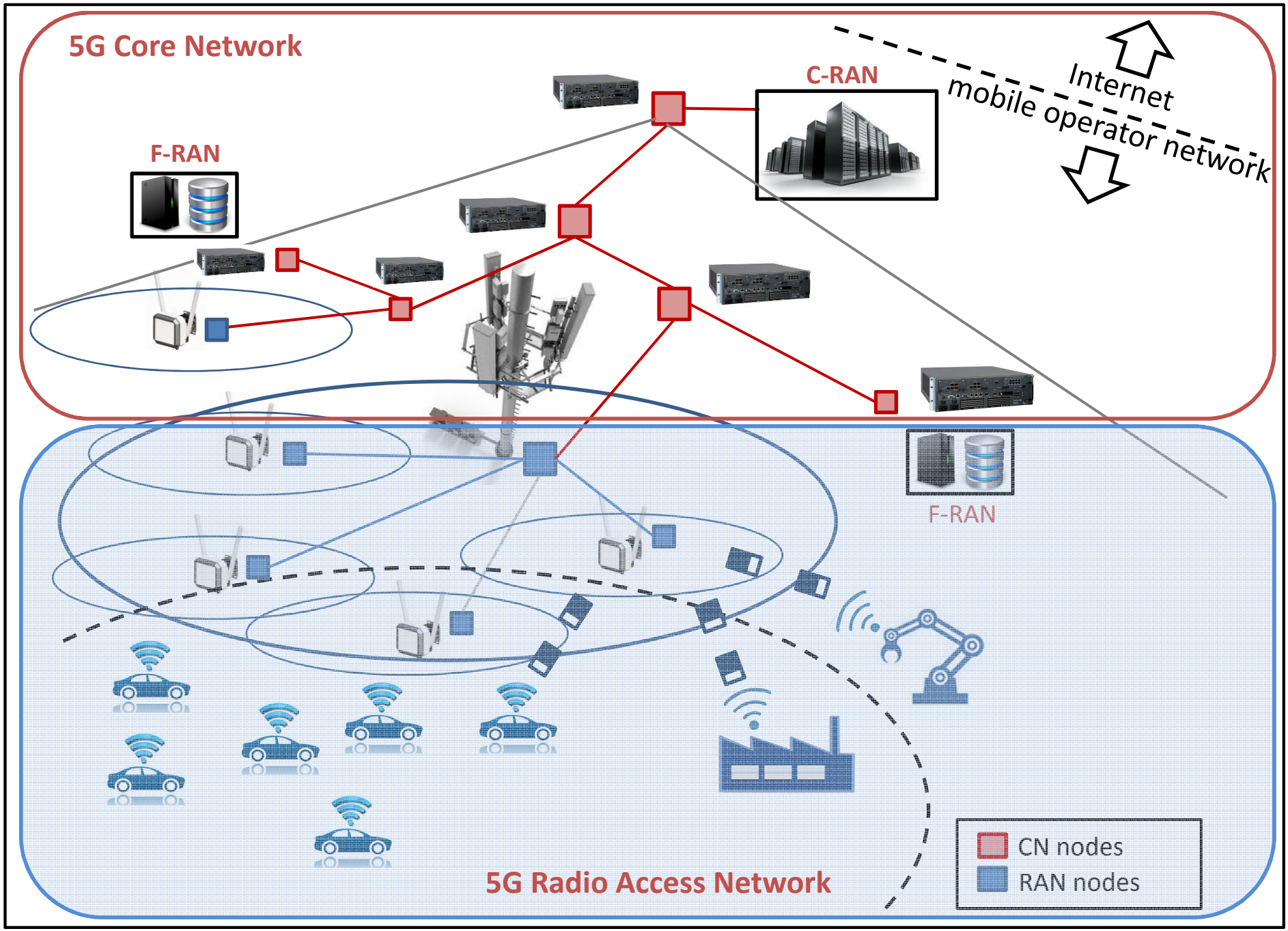
DEPARTMAN ZA ENERGETIKU, ELEKTRONIKU I TELEKOMUNIKACIJE

BigSkyEarth Workshop, 26.02.2018.


5G Core Network
C-RAN
Internet
mobile operator network
F-RAN
F-RAN
5G Radio Access Network
CN nodes
RAN nodes

Outline

- Massive MTC Communications
  - Machine-Type Communications in 4G/5G
  - Massive Uncoordinated Random Access
- Distributed Information Processing and Edge Computing
  - State Estimation in Smart Grids
  - State Estimation and Signal Detection in 5G C-RAN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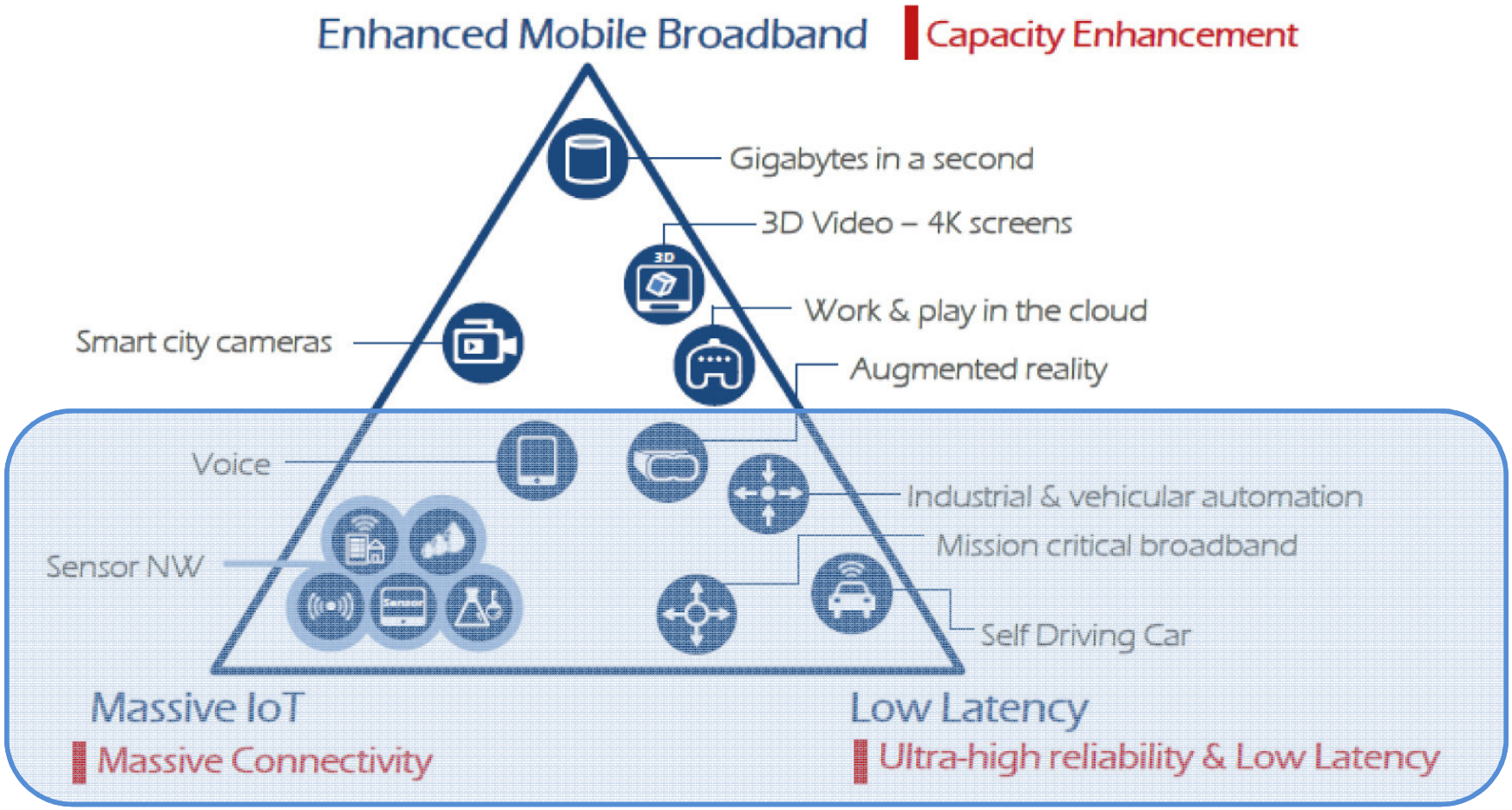
Machine-Type Communications



(Source: ETRI graphic, from ITU-R IMT 2020 requirements)

Machine-Type Communications

4G LTE/LTE-A/LTE-A Pro

- enhanced Machine-Type Communications (eMTC)
  - Cat-0 (6 PRB – 1.08 MHz)
- **Narrow-Band Internet of Things (NB-IoT)**
  - **Low-power Low-cost (1 RB – 180 kHz)**
- Extended Coverage GSM Internet of Things (EC-GSM-IoT)

5G New Radio

- massive Machine-Type Communications (mMTC)
  - 10^6 devices/km^2 satisfying packet loss rates less than 1%.
- Ultra-Reliable Low-Latency Communications (URLLC)
  - the generic DL/UL latency target is 0.5ms, while reliability targets packet loss rate of 10^{-5} for 32 byte packets and 1ms latency

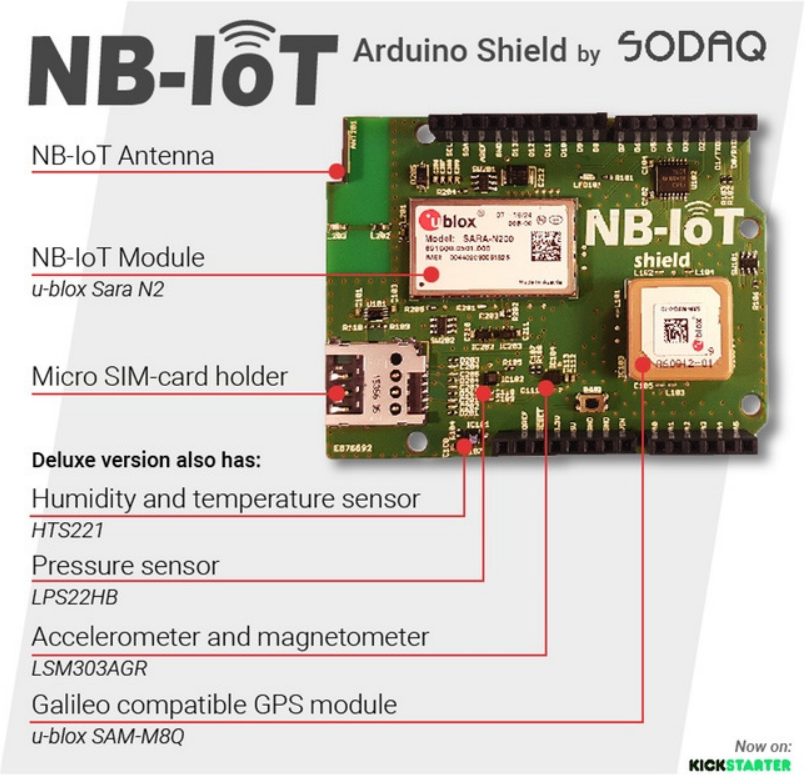
Rico-Alvarino, et al., "An overview of 3GPP enhancements on machine to machine communications," *IEEE Communications Magazine*, 54(6), pp.14-21, 2016.
Shariatmadari, et al. "Machine-type communications: current status and future perspectives toward 5G systems," IEEE Communications Magazine, 53(9), pp. 10-17, 2015.

3GPP NB-IoT

NarrowBand IOT

- Standardized within 3GPP Release 13 (Nov 2016)
- Already in testing/ deployment at many mobile operators
- Low-Power WAN
- Alternative to LoRa, SigFox
- “Next big thing” for mobile operators

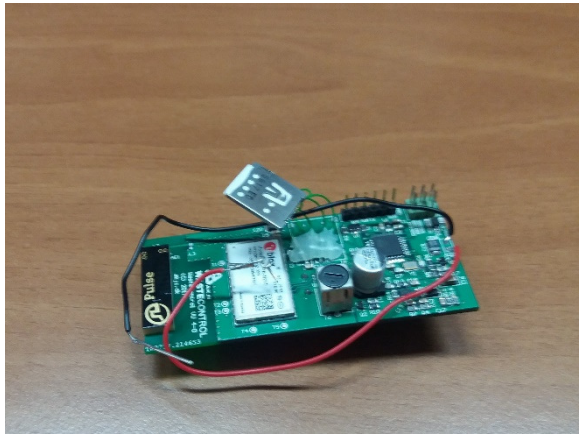
Early market solutions



https://shop.sodaq.com/en/nb-iot-shield-deluxe.html

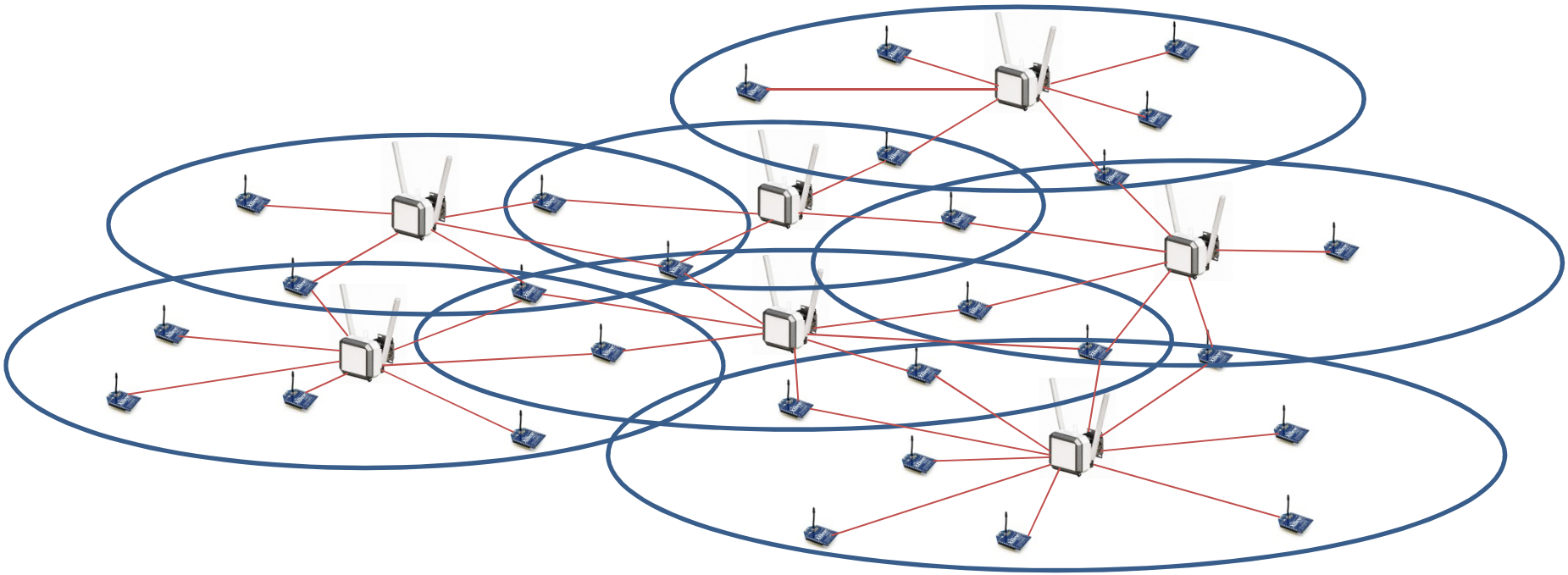
3GPP NB-IoT

Experiments with different designs with variety of sensor sets and NB-IoT chips targeting very low power consumption

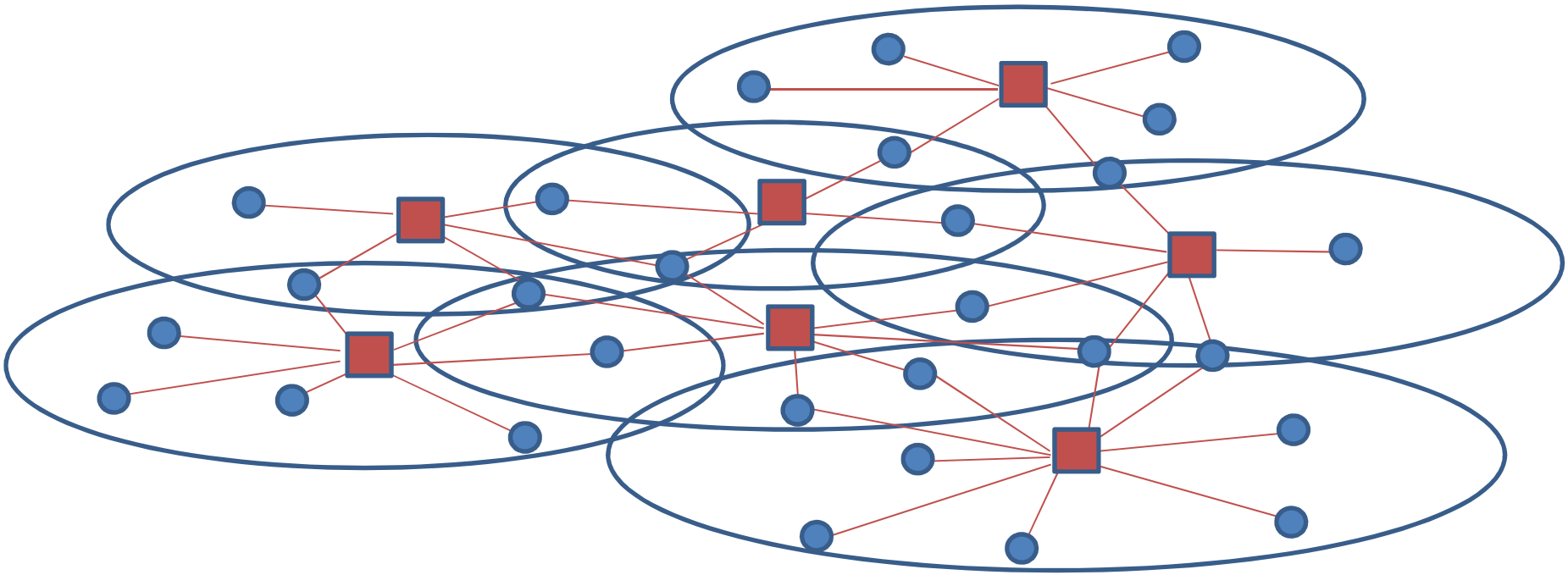


Very compact size of the device

Massive Uncoordinated Random Access



Approach: Modern Coding Theory
“Codes on Graphs”



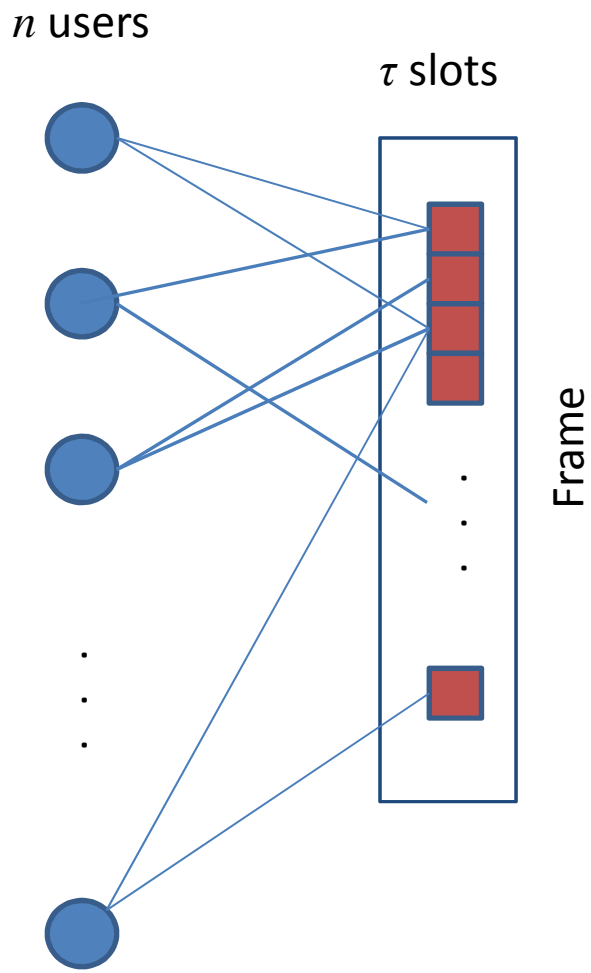
Collision Resolution Diversity Slotted ALOHA

CRD-SA protocol

- Users repeat transmissions in multiple slots
  - Repetition information in packet header
- Same number of repetitions per user

- Collisions can be exploited

- Iterative interference cancellation across slots



E. Casini, R. De Gaudenzi, O. del Rio Herrero, "Contention Resolution Diversity Slotted ALOHA: An Enhanced Random Access Scheme for Satellite Access Packet Networks", IEEE Trans Wireless Comms, April 2007.

Collision Resolution Diversity Slotted ALOHA

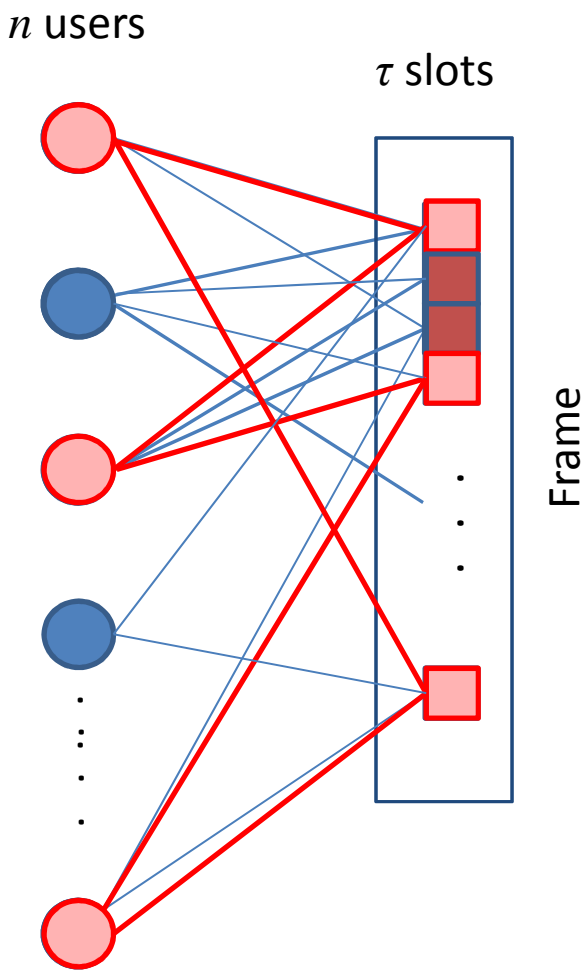
Iterative Interference Cancellation (IIC)

- Once the frame is finished, the base station performs IIC across time slots

- Iterative Interference Cancellation:
  - Detect and decode clean signal (singleton)
  - Remove its contribution from other slots
  - Repeat while possible

- Throughput:

  $T \approx 0.55$ for two repetitions per user



E. Casini, R. De Gaudenzi, O. del Rio Herrero, "Contention Resolution Diversity Slotted ALOHA: An Enhanced Random Access Scheme for Satellite Access Packet Networks", IEEE Trans Wireless Comms, April 2007.

Coded Slotted ALOHA

IRSA protocol

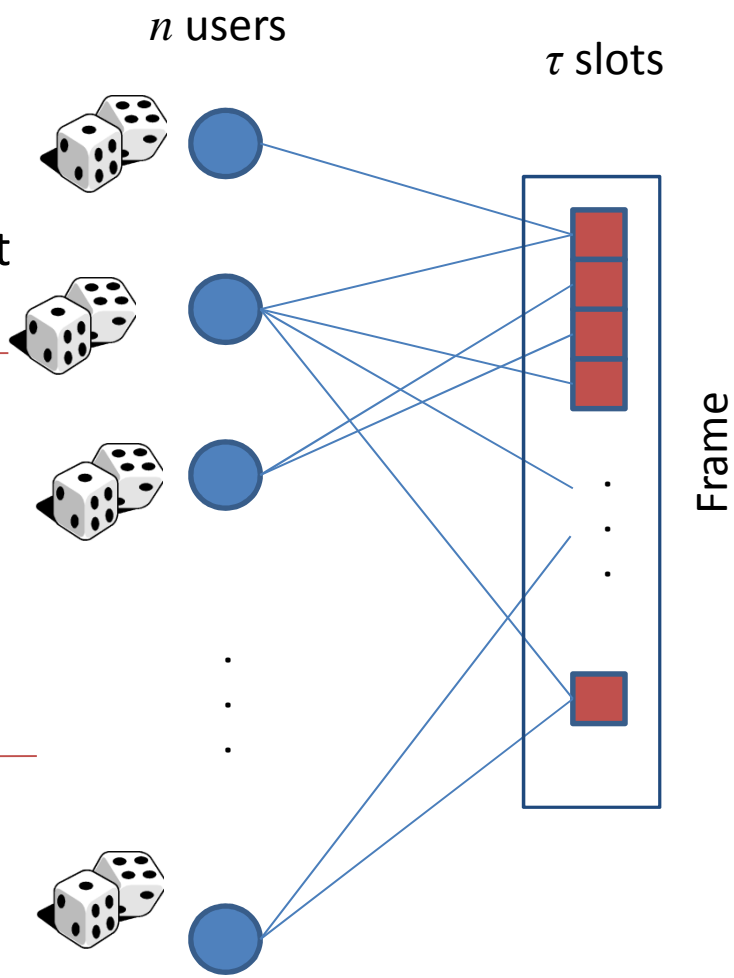
- Iterative interference cancellation equivalent to iterative erasure decoding of LDPC codes

G. Liva, "Graph-Based Analysis and Optimization of Contention Resolution Diversity Slotted ALOHA," IEEE Transactions on Communications, February 2011.

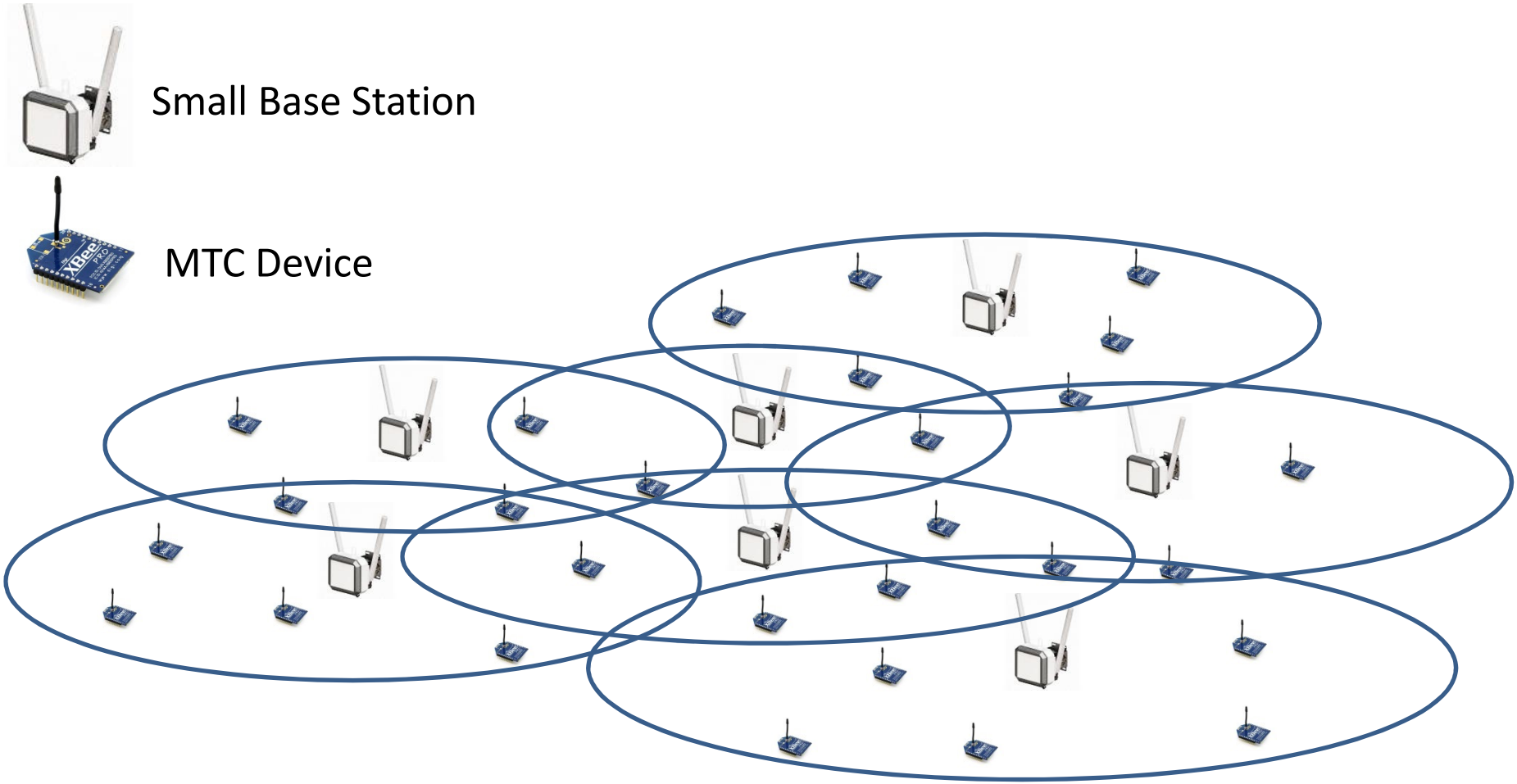
Frameless ALOHA

- Idea: Instead of applying ideas from LDPC codes, apply paradigm of rateless codes

C. Stefanovic, P. Popovski, D. Vukobratovic, "Frameless ALOHA Protocol for Wireless Networks", IEEE Communication Letters, December 2012.

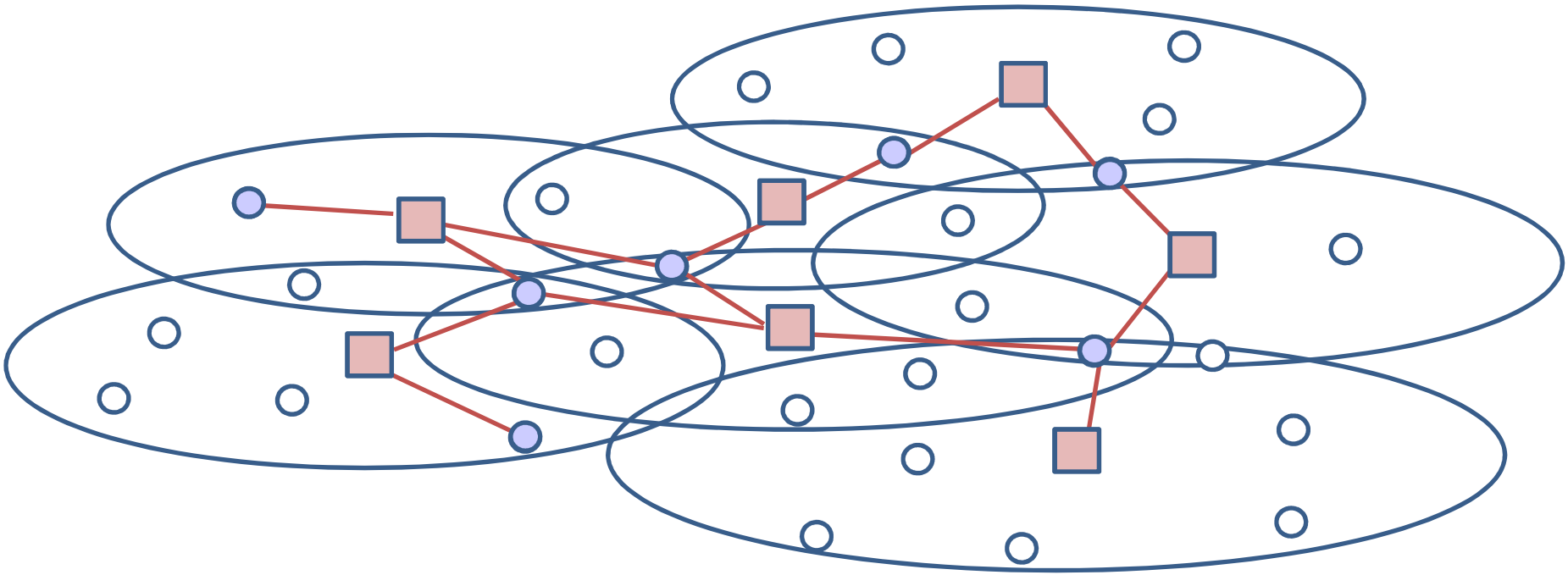


Multiple Base Station Model

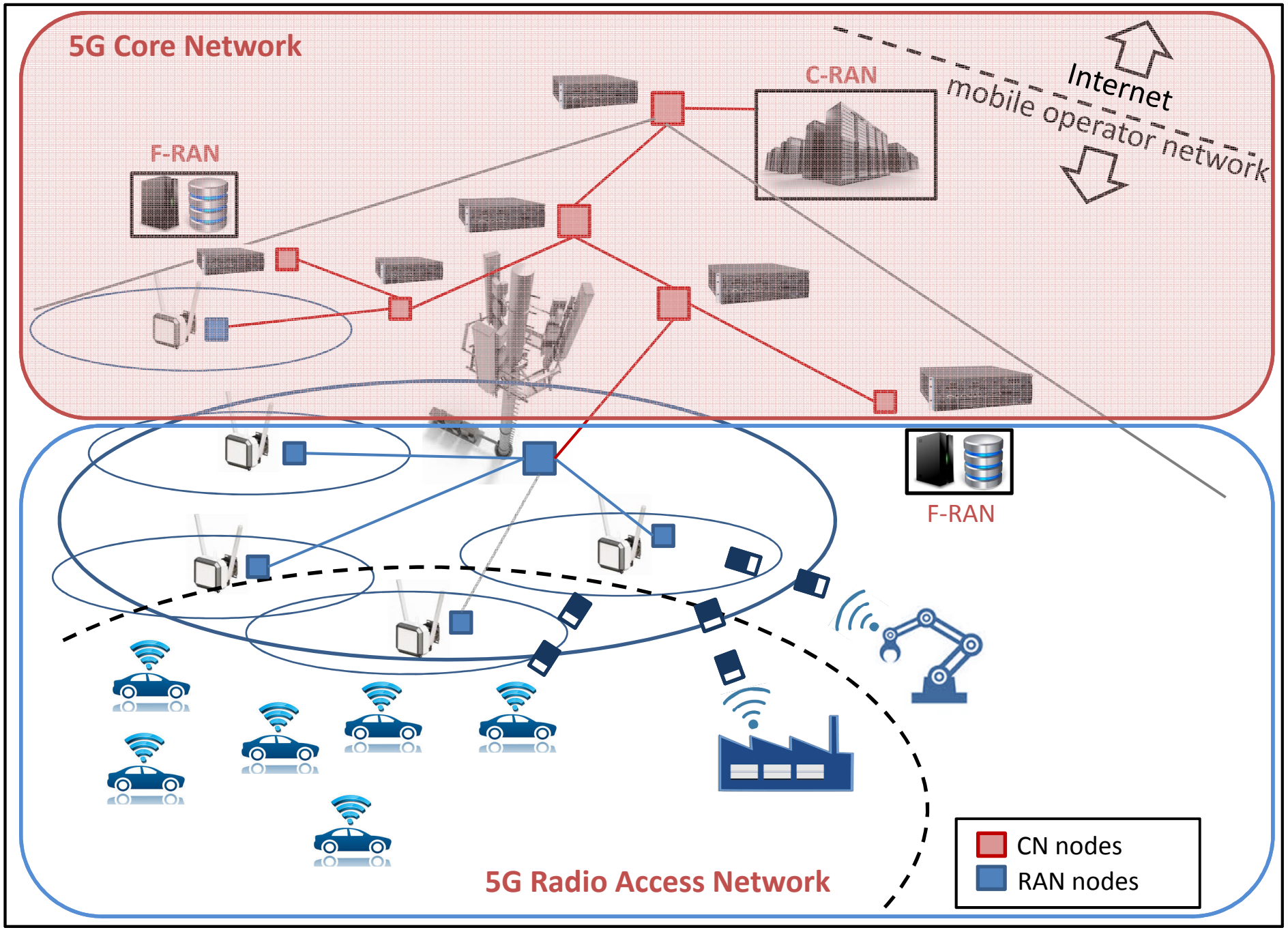


D. Jakovetic, D. Bajovic, D. Vukobratovic, V. Crnojevic, “Cooperative Slotted ALOHA for Multi-Base Station Systems” IEEE Transactions on Communications, Vol. 63, No. 4, pp. 1443-1456, April 2015.

Decoding via Spatial Cooperation



D. Jakovetic, D. Bajovic, D. Vukobratovic, V. Crnojevic, “Cooperative Slotted ALOHA for Multi-Base Station Systems” IEEE Transactions on Communications, Vol. 63, No. 4, pp. 1443-1456, April 2015.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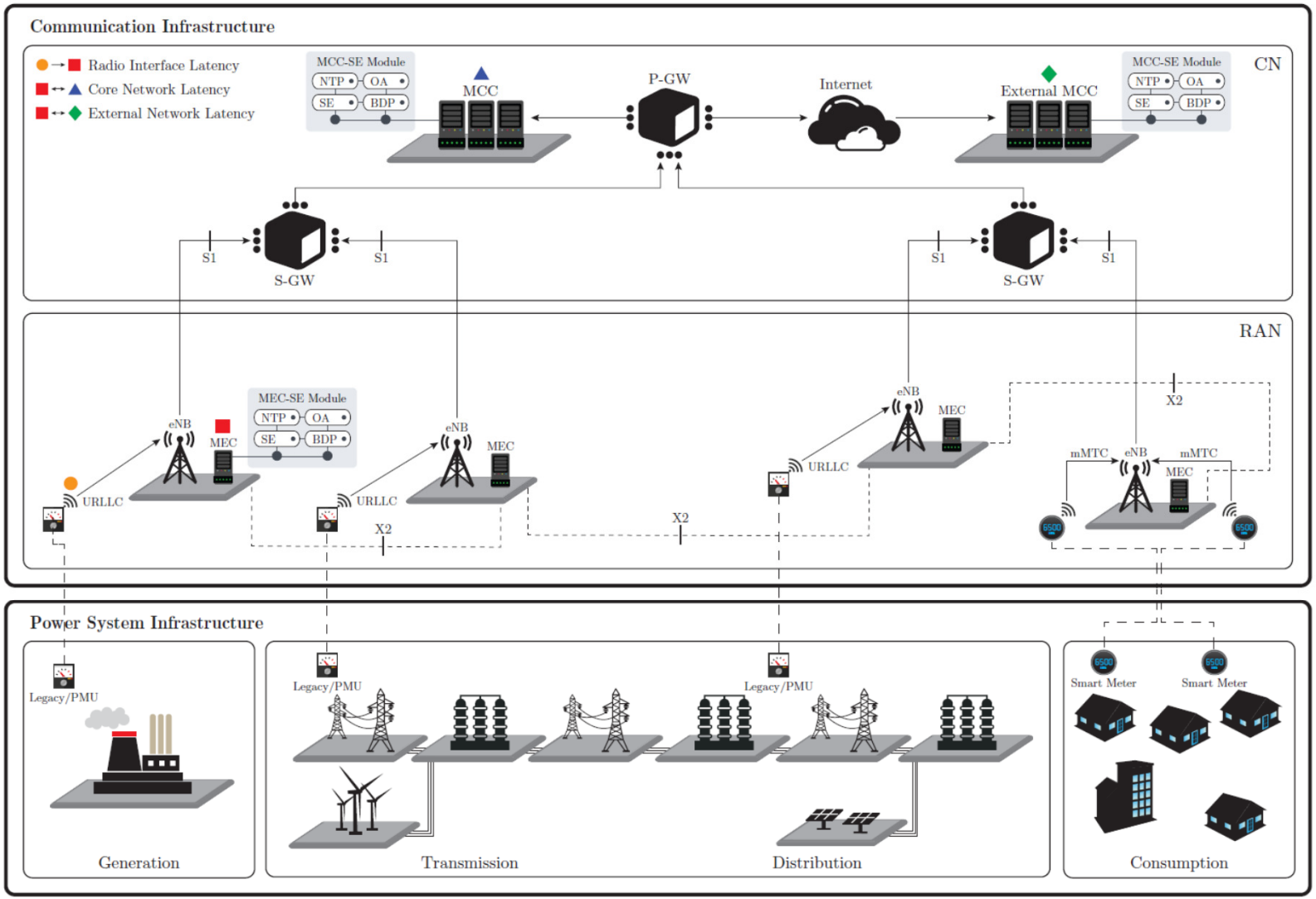
Mobile Edge Computing

Mobile Edge Computing (MEC)

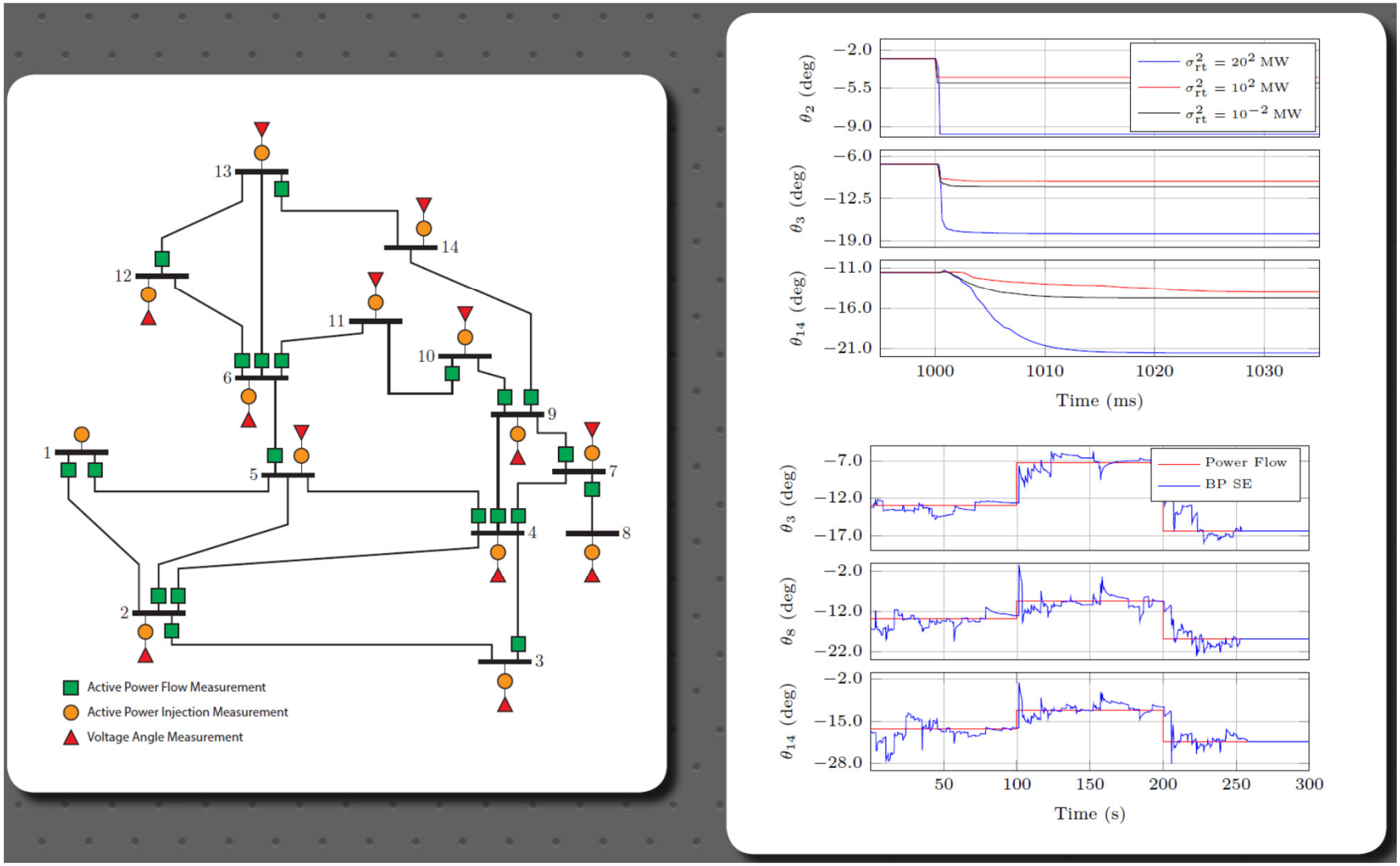
- Provides computing and caching at or in proximity of mobile network base stations
- Large number of geographically distributed **MEC hosts**
- **Network Function Virtualization (NFV)**
  - Make network functions or user services available at any MEC host
- **Software Defined Networking (SDN)**
  - Connect different virtualized services/apps flexibly using SDN concepts
- Complements (not in collision) with Mobile Cloud Computing

Distributed State Estimation in Power Systems



M. Cosovic, A. Tsitsimelis, D. Vukobratovic, J. Matamoros, C. Anton-Haro: 5G Mobile Cellular Networks: Enabling Distributed State Estimation for Smart Grids, IEEE Communications Magazine, October 2017.

Distributed SE Using Belief Propagation

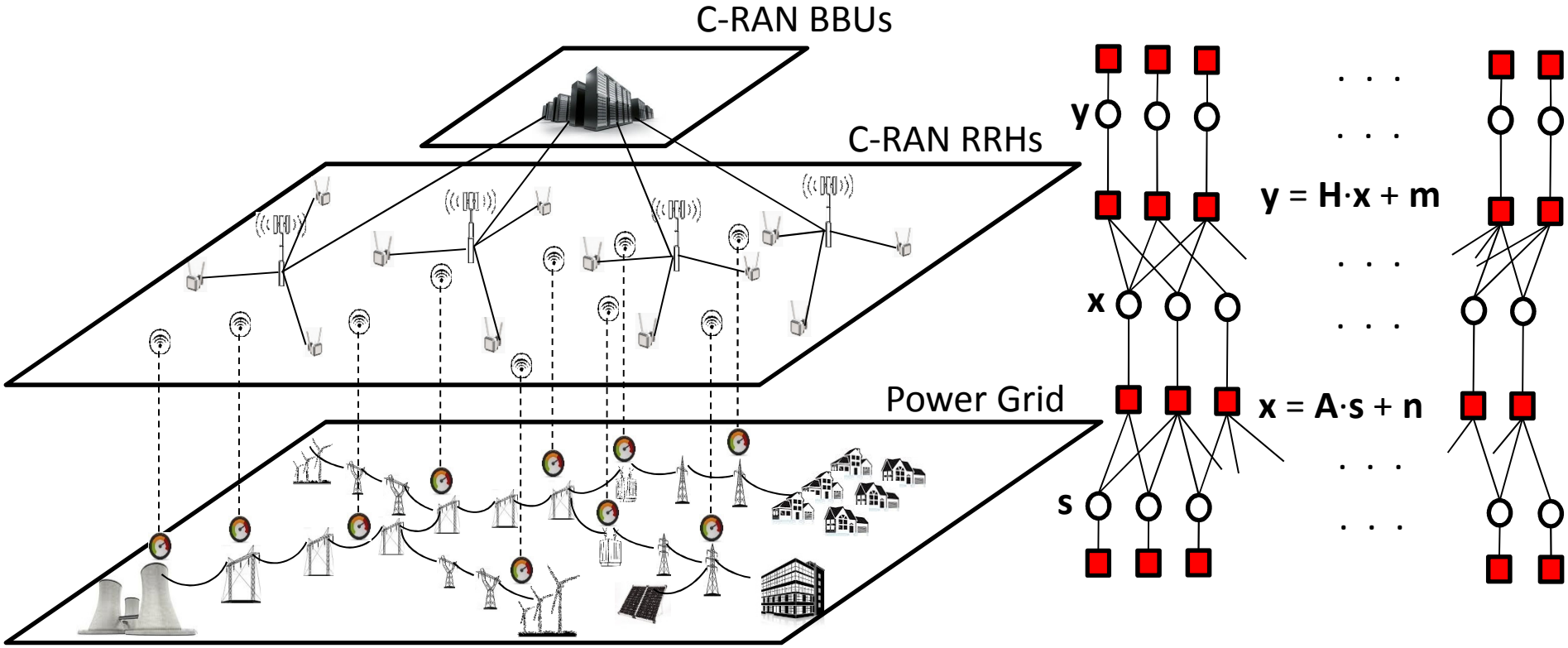


M. Cosovic, D. Vukobratovic: Distributed State Estimation in Power Systems Using Belief Propagation, submitted, IEEE Transactions on Power Systems (Arxiv link: arxiv.org/abs/1702.05781)

M. Cosovic, D. Vukobratovic: Fast Real-Time DC State Estimation in Power Systems Using Belief Propagation, IEEE SmartGridComm 2017, Dresden, Germany (Arxiv link: arxiv.org/abs/1705.01376) (**Best Student Paper Award**)

Ongoing work…

Joint linear system state estimation and uplink signal detection in C-RAN



- Can we estimate system state **s** directly from received signals **y**?
- How can we do efficiently and scalably it in a large-scale scenario? (GBP)

M. Cosovic, D. Vukobratovic, V. Stankovic: Linear State Estimation via 5G C-RAN Cellular Networks using Gaussian Belief Propagation, IEEE Wireless Communications and Networking Conference WCNC 2018, Barcelona, April 2018 (Arxiv link: arxiv.org/abs/1710.08671)

Summary

- **5G Machine Type Communications**: Provide 5G network with possibility to aquire data from billions of devices
- **5G Mobile Edge Computing**: provides large-scale distributed environment for complex computation and control

H2020-MCSA-RISE-2016 Marie Curie (734331): "SENSIBLE": Smart Sensing in Built Environment, 2017-2021.
FP7-PEOPLE-ITN-2013 Marie Curie (607774): "ADVANTAGE": Advanced communication and information processing for Smart Grid systems, 2014-2018.