UNIVERSITEIT GENT

FACULTEIT INGENIEURSWETENSCHAPPEN

Cooperative Cognitive Networks

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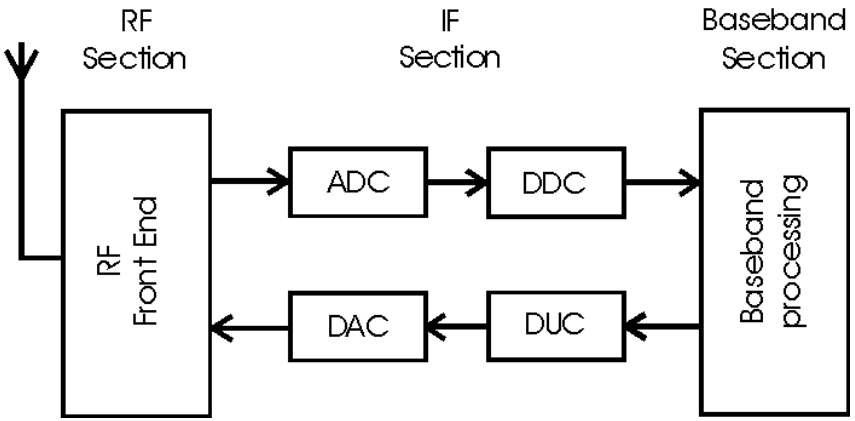
BACKGROUND

Software Defined Radio

A software-defined radio, or SDR, is a radio communication system where components that have been typically implemented in hardware (e.g. mixers, filters, amplifiers, modulators/demodulators, detectors) are instead implemented in software

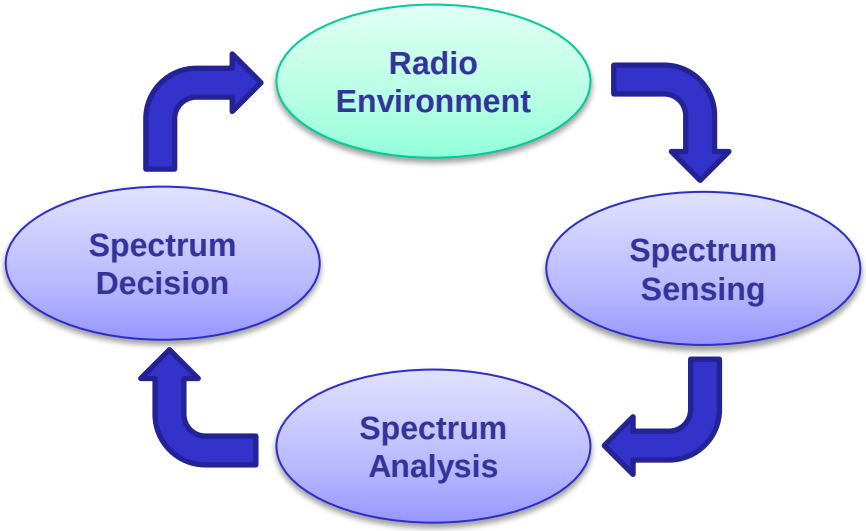
- Originates in the late 1970s
- Primary goal: emulate on one platform different radio communication systems that operate in different frequency bands
- Focus: Layer 1



Cognitive Radio

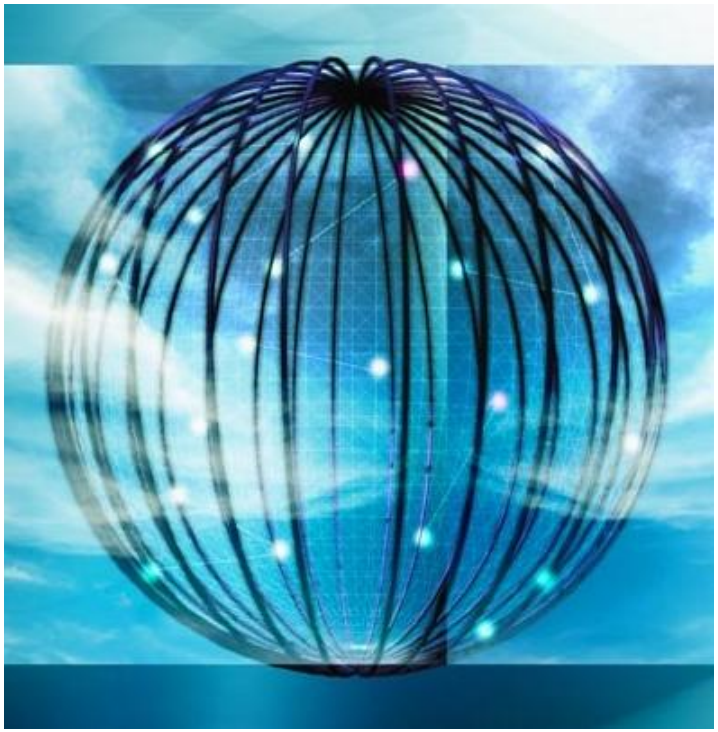
Cognitive radio is a paradigm for wireless communication in which either a network or a wireless node changes its transmission or reception parameters to communicate efficiently avoiding interference with licensed or unlicensed users

- Originates in the late 1990s
- Primary goal: make use of under-utilized spectrum
- Focus: Layer 1 and 2



Cognitive Network

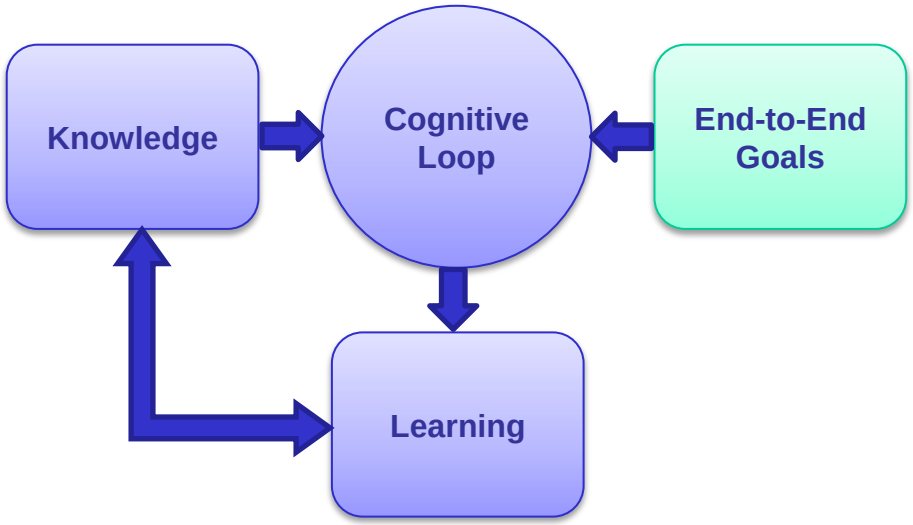
Cognitive network is a new type of data network that makes use of cutting edge technology from several research areas (i.e. machine learning, knowledge representation, computer network, network management) to solve some problems current networks are faced with



- **Originates in the mid 2000s**
- **Focus: All Layers of the OSI model**

Two Major Elements

- knowledge plane that can span vertically over layers and horizontally across technologies and nodes (covering a heterogeneous environment)
  - A representation of relevant knowledge about devices, networks, etc.
- Cognition loop which uses Artificial Intelligence techniques
  - Sense the environment
  - Plan actions according to input from sensors and network policies
  - Decide which scenario fits best the end-to-end purpose
  - Act on the chosen scenario

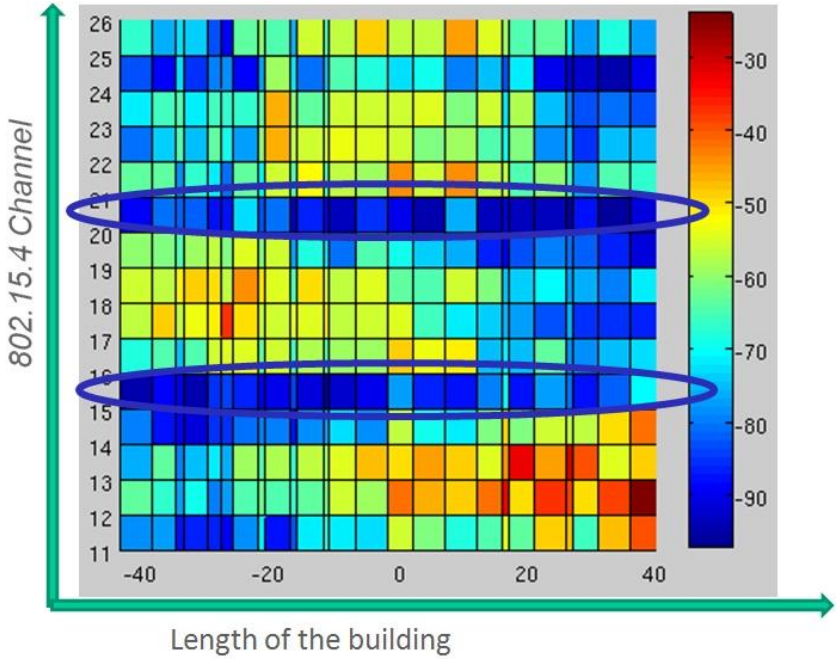


INTERFERENCE AVOIDANCE

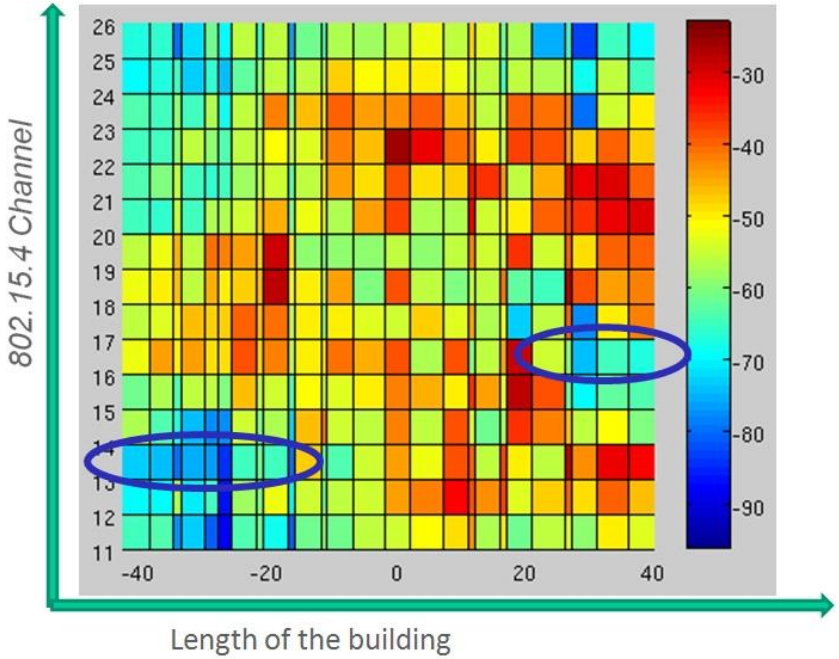
Interference Avoidance

- **The 2.4 GHz ISM Band is Over-crowded**
- **Measured Interference in real-life testbed network**
  - **18 nodes along 90 meters in one floor of the IBCN office**
  - **All channels of IEEE 802.15.4 in 2.4 GHz ISM Band**

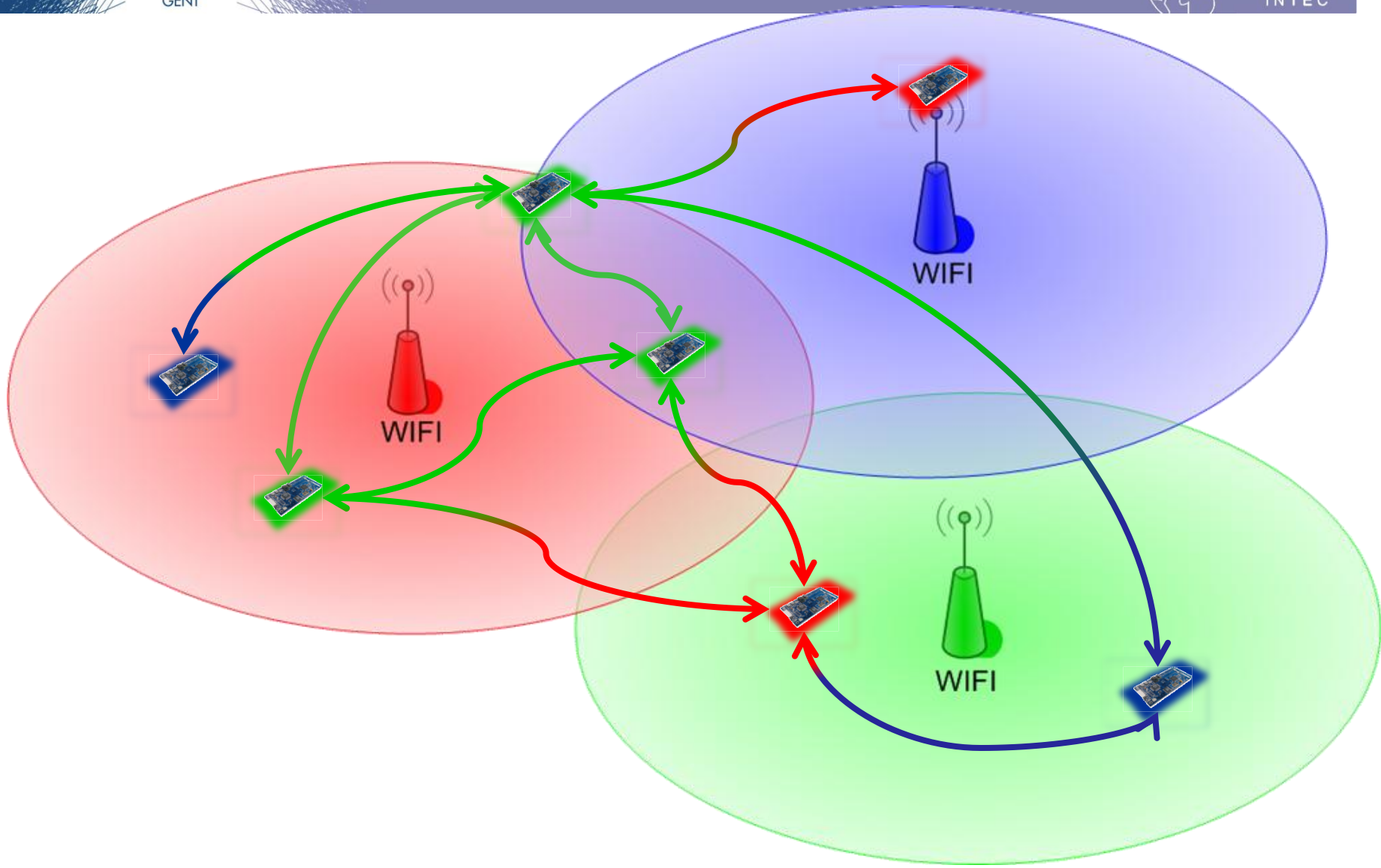
Night-time



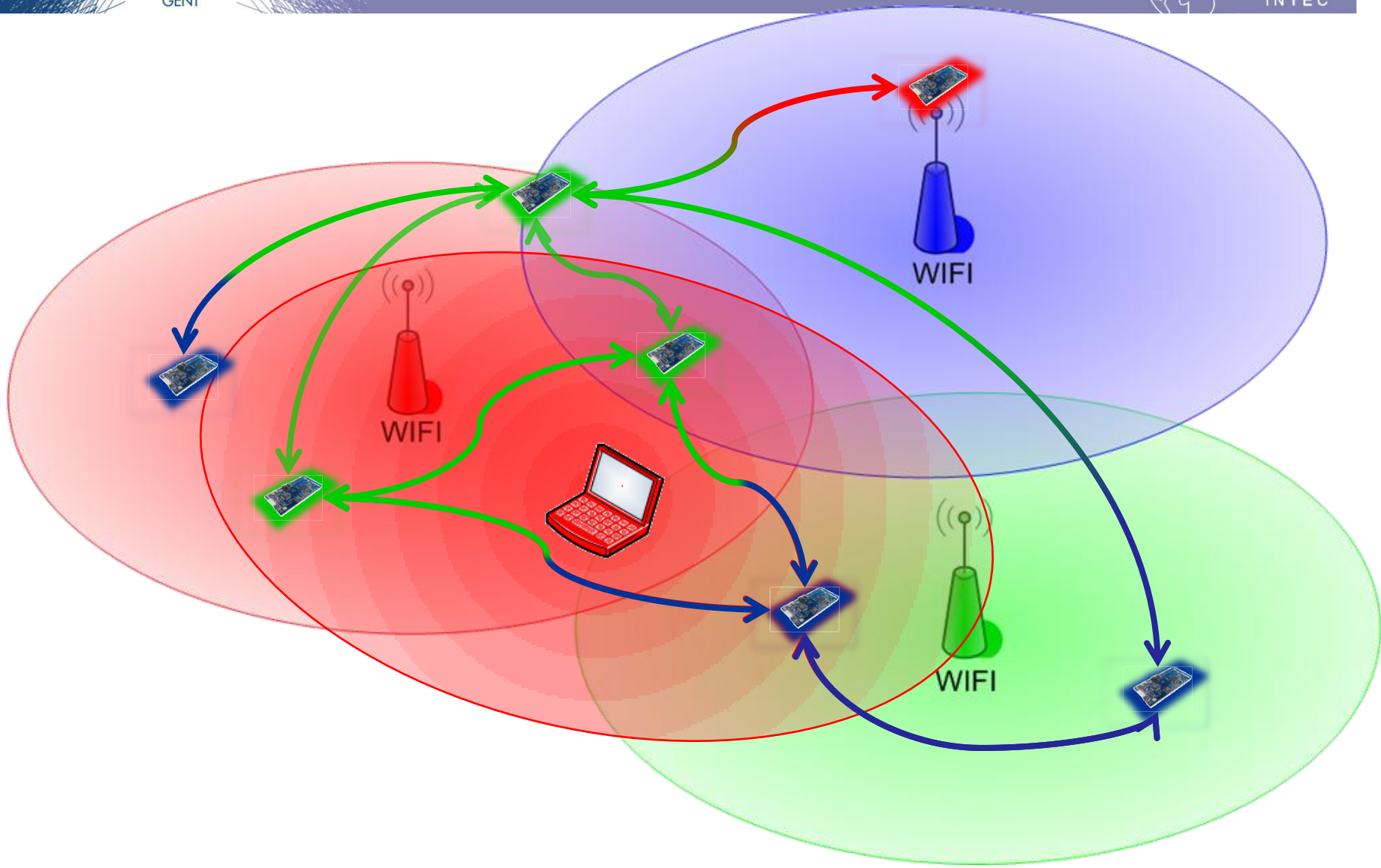
Daytime



Interference Avoidance



Interference Avoidance

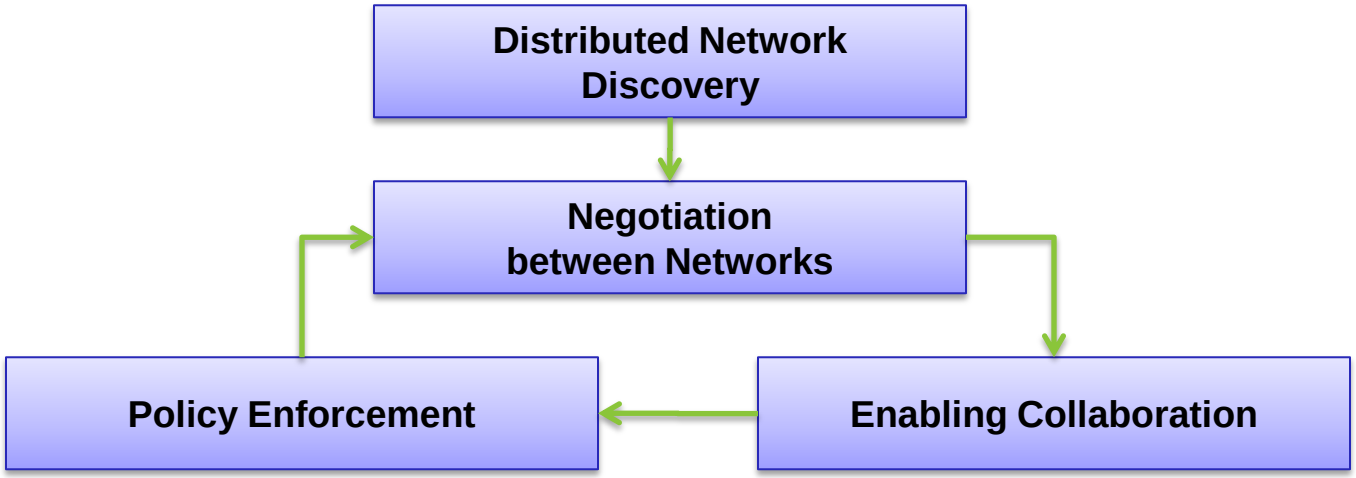


Comparison of Packet Error Rate (PER) between Best Single Channel (red) and Receiver Defined Transmission (green)

PER (%)	Night Time		Day Time	
Network Average	0.53	0.34	3.57	2.13
Worst Node	2.03	4.19	9.18	7.26

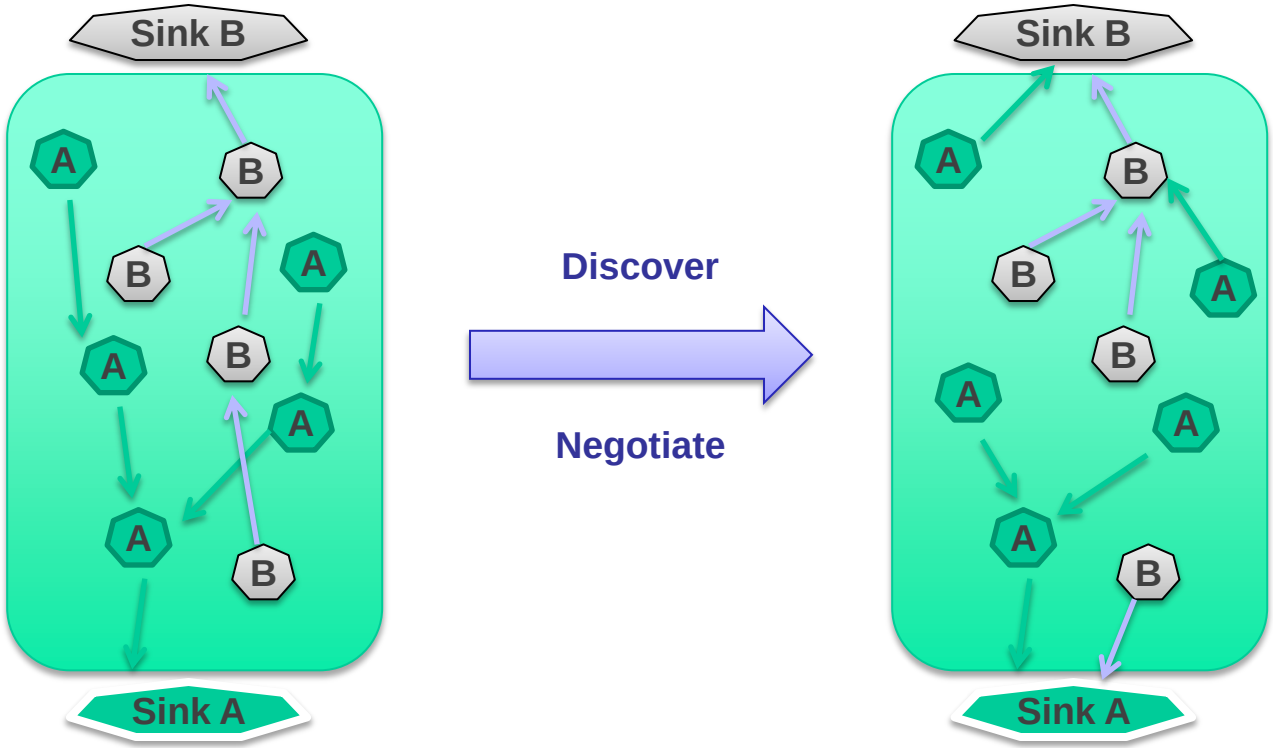
NETWORK COLLABORATION

Co-located Networks can Gain from Collaborating



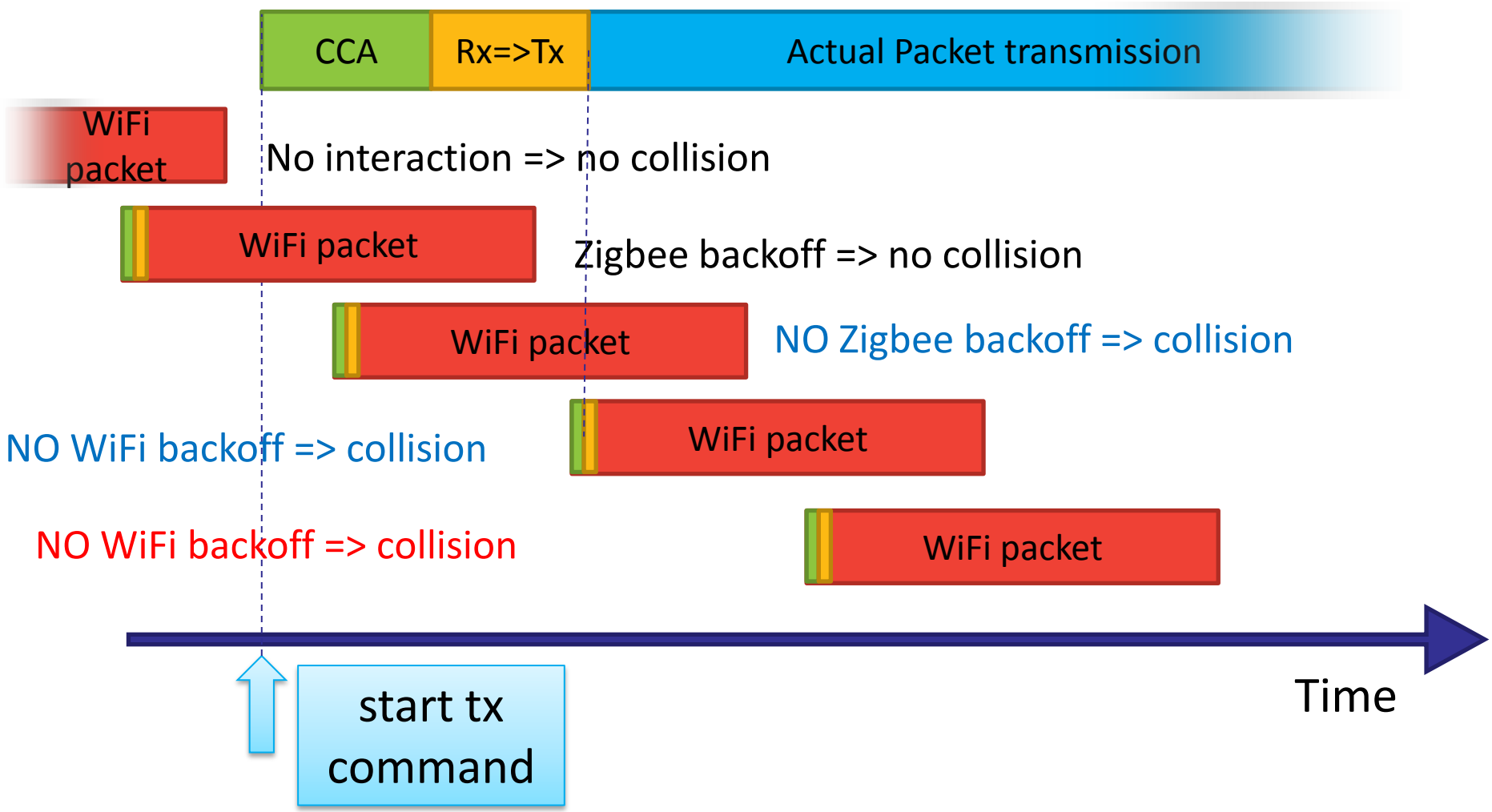
Network Collaboration

- Network A: security network
  - Incentives: low delay, high throughput
- Network B: temperature monitoring
  - Incentives: high network lifetime



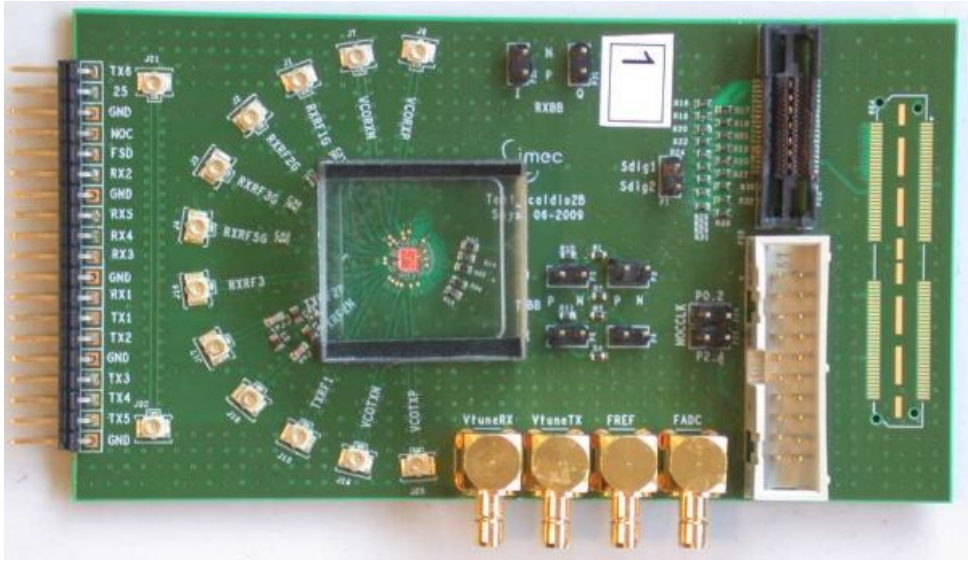
SPECTRUM SENSING

Zigbee and WiFi CCA



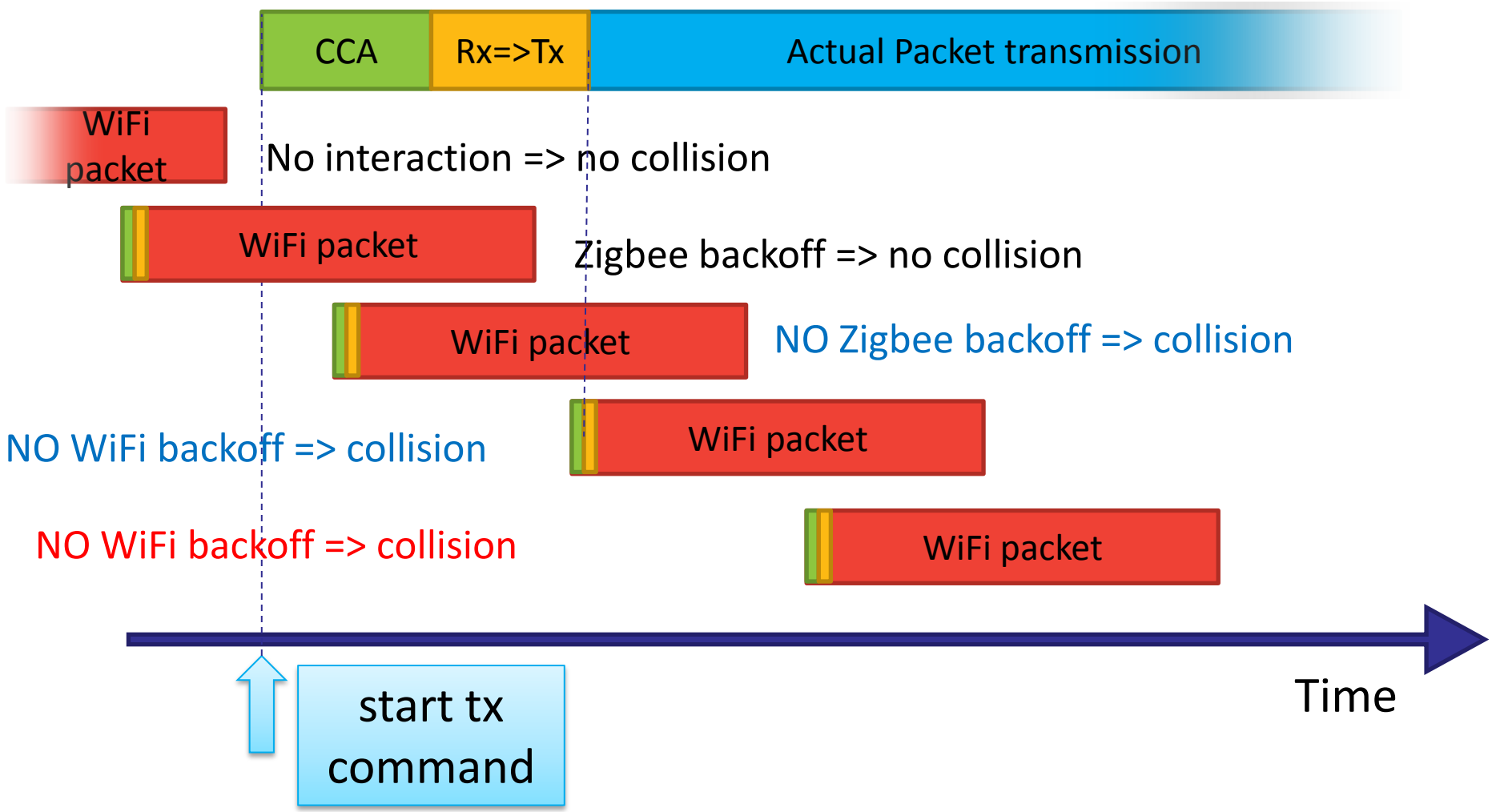
Cross Technology CCA

- **Spectrum Sensing Engine by imec**
  - **Accurate Spectral overview**
  - **High speed detection**

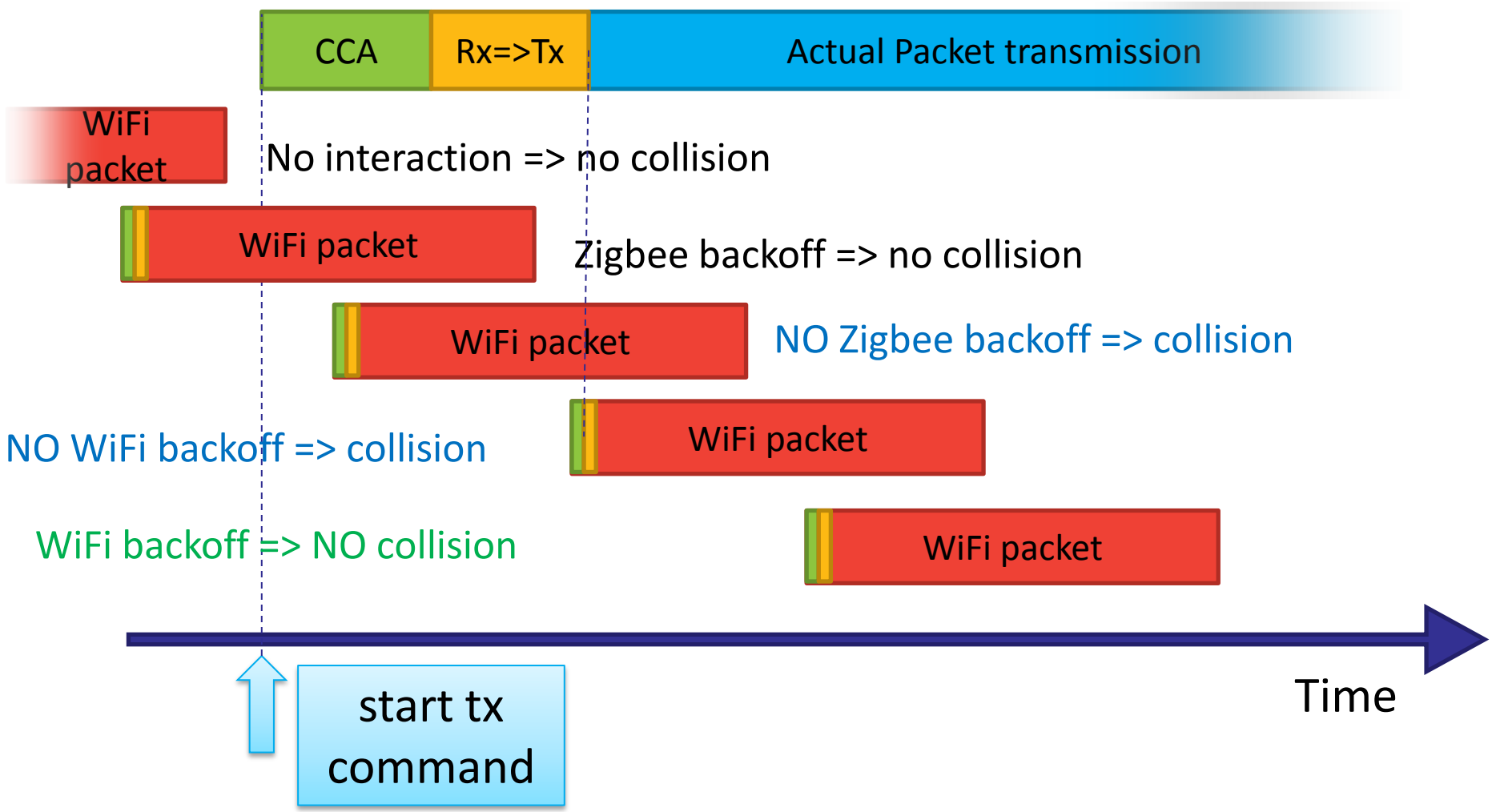


- **Sensing Engine as CCA module (SE-CCA)**
  - **Faster CCA for Zigbee**
  - **Enables WiFi to detect Zigbee**

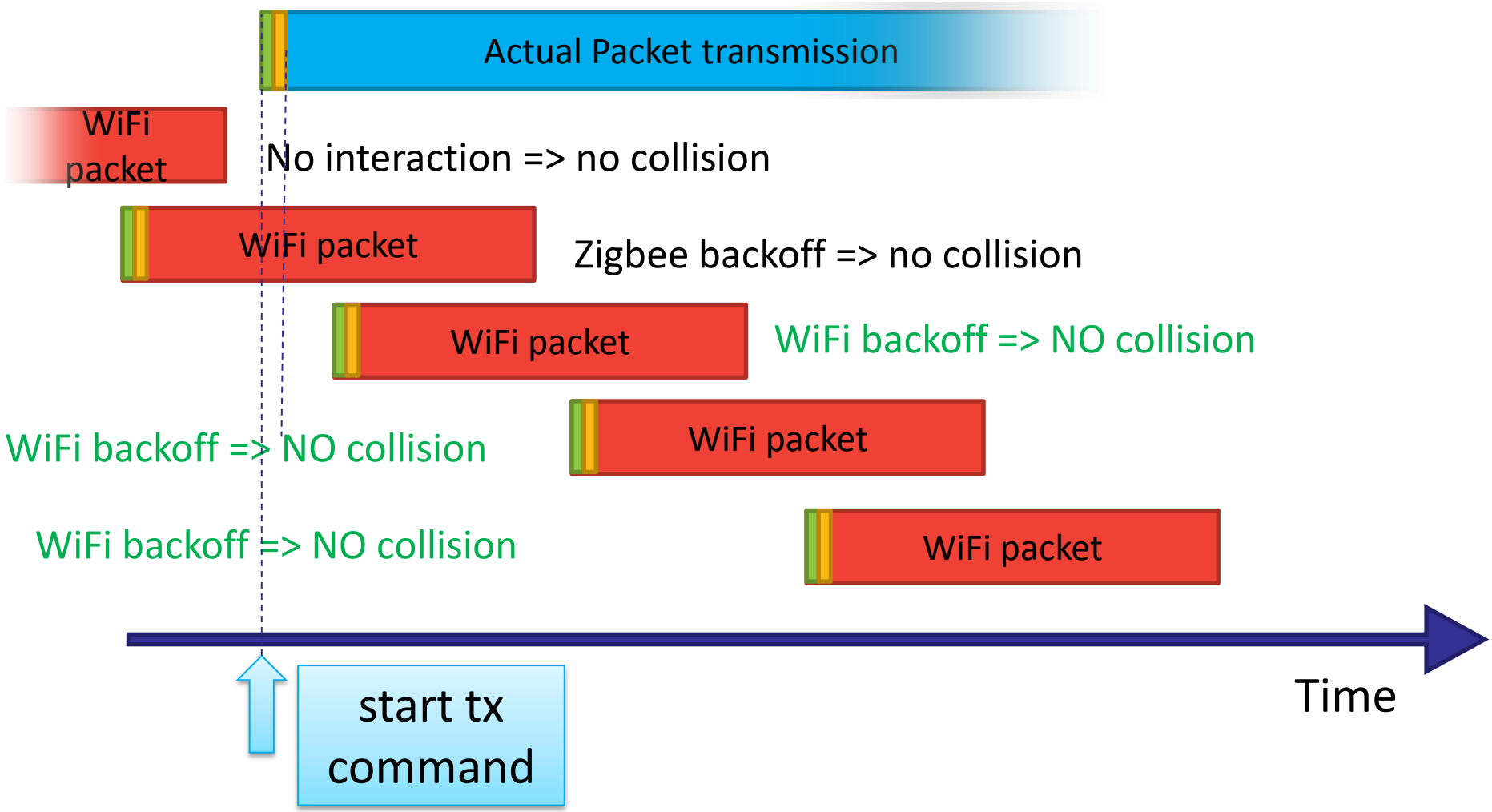
No SE-CCA


CCA
Rx=>Tx
Actual Packet transmission
WiFi packet
No interaction => no collision
WiFi packet
Zigbee backoff => no collision
WiFi packet
NO Zigbee backoff => collision
WiFi packet
NO WiFi backoff => collision
NO WiFi backoff => collision
WiFi packet
Time
start tx command

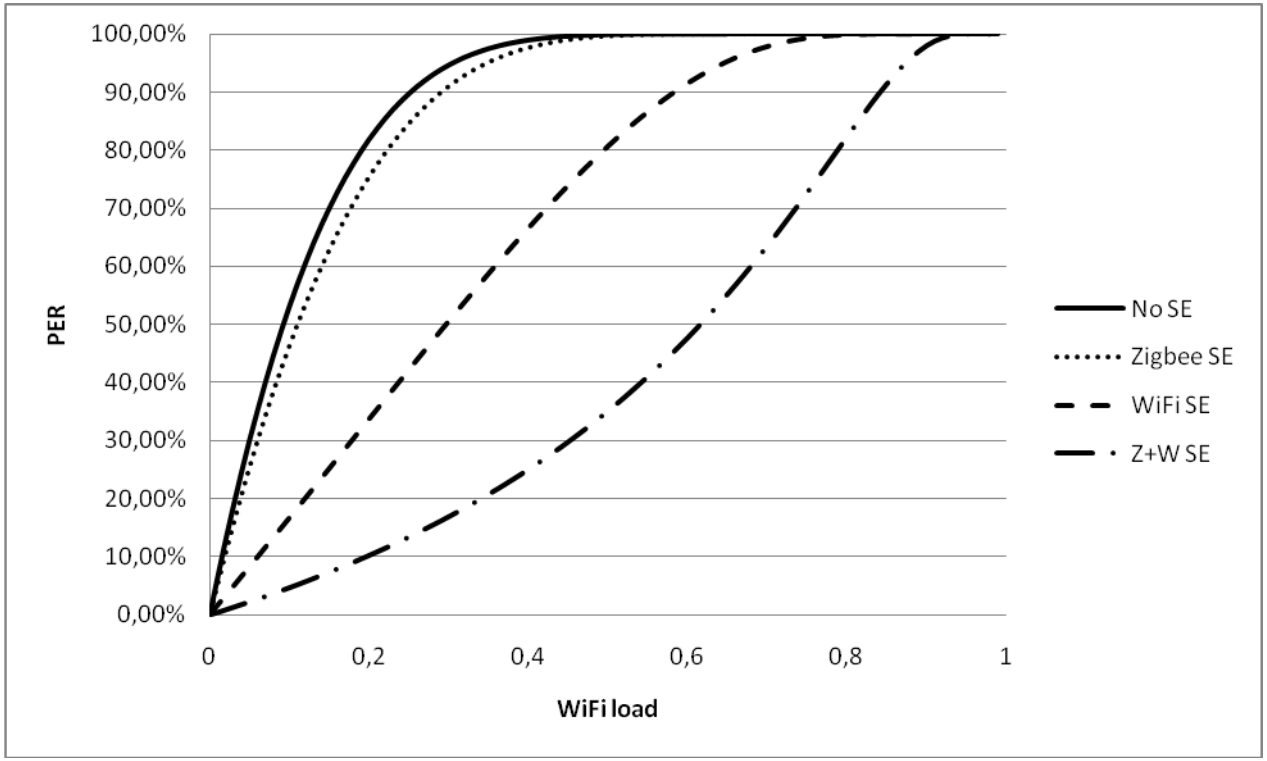
SE-CCA for WiFi



Add SE-CCA to ZigBee



SE-CCA Effect on Zigbee PER



Summary

- **Wireless Networks Proliferate**
  - **Technologies**
  - **Number and Size of Networks**
- **Wireless Spectrum is Scarce, and Utilized Sub-Optimally**
- **Collaborative Cognitive Networking is the Way Forward**
  - **Mechanisms are developed and studied**
  - **Still no workable solution exists**
  - **Exciting road lies ahead**

Challenges for Further Research

- **Cooperative channel selection**
  - **Clustering of nodes on single channels**
  - **Distributed cooperation algorithms**
  - **Global optimization**
- **Inter-technology network collaboration**
  - **Inter-technology detection and negotiation**
  - **Inter-technology collaboration mechanisms**
  - **Policy Monitoring and Enforcement**
- **Distributed sensing of the wireless environment**
  - **Combine sensing information from different sources**
  - **Learning of the wireless environment**
  - **Utilization of knowledge in cognitive networks**

Questions?