# University of Dodoma
# College of Informatics and Virtual Education
# School of Informatics


Mnyawami Yuda
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**MSc Information Technology**
**Name of Lecturer:** Mr. Faustine Antony

**COGNITIVE RADIO**

# Outline:

- Introduction in 5G
- What drives 5G?
- CR in 5G
- Cognitive Cellular Networks
- Future Research Directions
- Conclusion

# Introduction in 5G

- Data Rates
- Capacity
- Spectrum
- Energy
- Latency
- Reliability
- Coverage
- Devices per area

# What drives 5G?

**Mobile data demand will continue to increase.**
Growth of existing applications.

- E-mail,
- File transfer,
- Real-time audio (VoIP),
- Video streaming,
- IP traffic,

# What drives 5G?

**New applications and new ways of doing things .**

- Instant Messaging (IM) with big files: lots of short connections, high data rates.
- Internet-of-Things (IoT) and Machine-to-Machine (M2M): massive numbers of devices and connections, little data more than 50 billions of connected devices in 2020.
- Critical applications - e.g., health, safety and security, traffic systems: guaranteed QoS.

# Meaning of Cognitive Radio

It is an intelligent wireless communication system that is aware of its surrounding environment (i.e., outside world), and uses the methodology of understanding by building to learn from the environment and adapt its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters (e.g., transmit power, carrier frequency and modulation strategy) in real-time, with two primary objectives in mind: highly reliable communications whenever and wherever needed; and efficient utilization of the radio spectrum.

# The Motivation behind Cognitive Radio

**Significant underutilization of the radio spectrum.**
**The Cognitive Radio solution to the spectrum underutilization problem:**

- Sense the radio environment to detect spectrum holes (i.e., underutilized subbands of the radio spectrum).
- Make the spectrum holes available for employment by secondary users efficiently, subject to the constraint that the received power in each spectrum hole does not exceed a prescribed limit (set by the legacy user).

# How it works

**The cognitive radio network is a complex multiuser wireless communication system capable of emergent behaviour.**
**It embodies the following functions:**

- To perceive the radio environment (i.e., outside world) by empowering each users receiver to sense the environment on a continuous-time basis;
- To learn from the environment and adapt the performance of each transceiver (transmitter-receiver) to statistical variations in the incoming RF stimuli;

# How it works cont..

- To facilitate communication between multiple users through cooperation in a self-organized manner;
- To control the communication processes among competing users through the proper allocation of available resources;
- To create the experience of intention and self-awareness.

# Why may CR be interesting for 5G?

- Some bands are significantly underutilized
- Cost of dynamically leasing spectrum is expected to be much lower than purchasing a licensed band
- Allows expansion of spectrum at a much lower cost
- Coping with overload traffic

# Cognitive cellular networks

**Cognitive cellular networks**

Employs cognitive radio to lease addition spectrum outside the licensed cellular bands.

The radio resource(RR) at a particular band can be characterized by;

- Bandwidth
- Maximum transmit power
- Reliability (or availability)

# Cognitive cellular networks

**The RRs in a cognitive cellular network include;**

- Licensed (cellular band) RR
- Cognitive RR

**Licensed radio resources (cellular bands)**

- Small bandwidth
- High transmit power
- High reliability

**Cognitive radio resources**

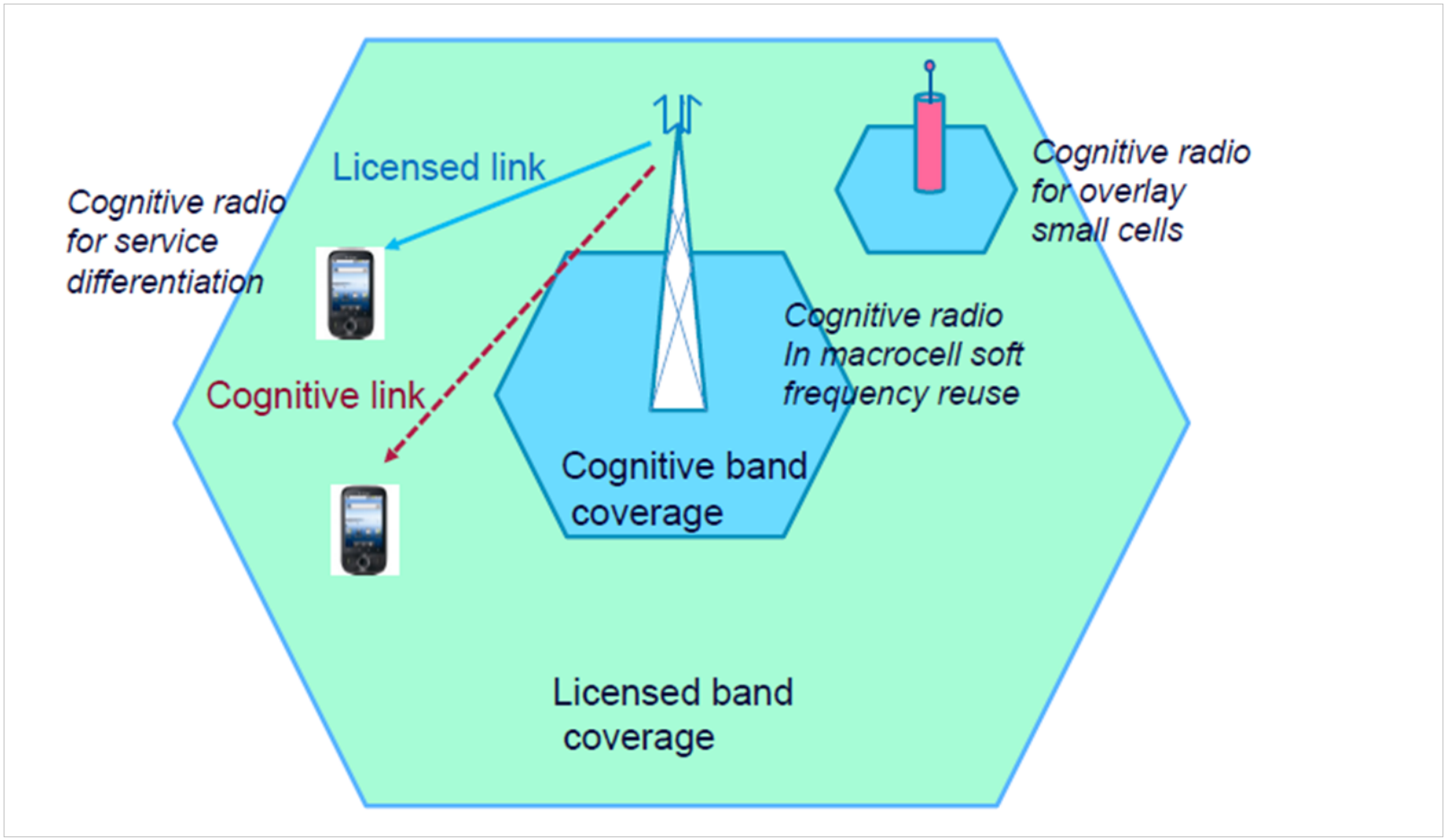
- Potentially broad bandwidth
- Low transmit power
- Low reliability

It enables a cognitive cellular network to effectively integrate conventional licensed radio and cognitive radio into a holistic system. The architectures of cognitive cellular networks can be categorized broadly into two types: non-cooperative and cooperative

# Non-Cooperative Architecture

- From figure below, there are two separate radio interfaces operating at the licensed and cognitive RRs.
- The cognitive RR is used to build a new network (i.e., a standalone cognitive network) that overlays the existing licensed cellular network.
- Two separated networks at the physical layer
- Integration at upper layers

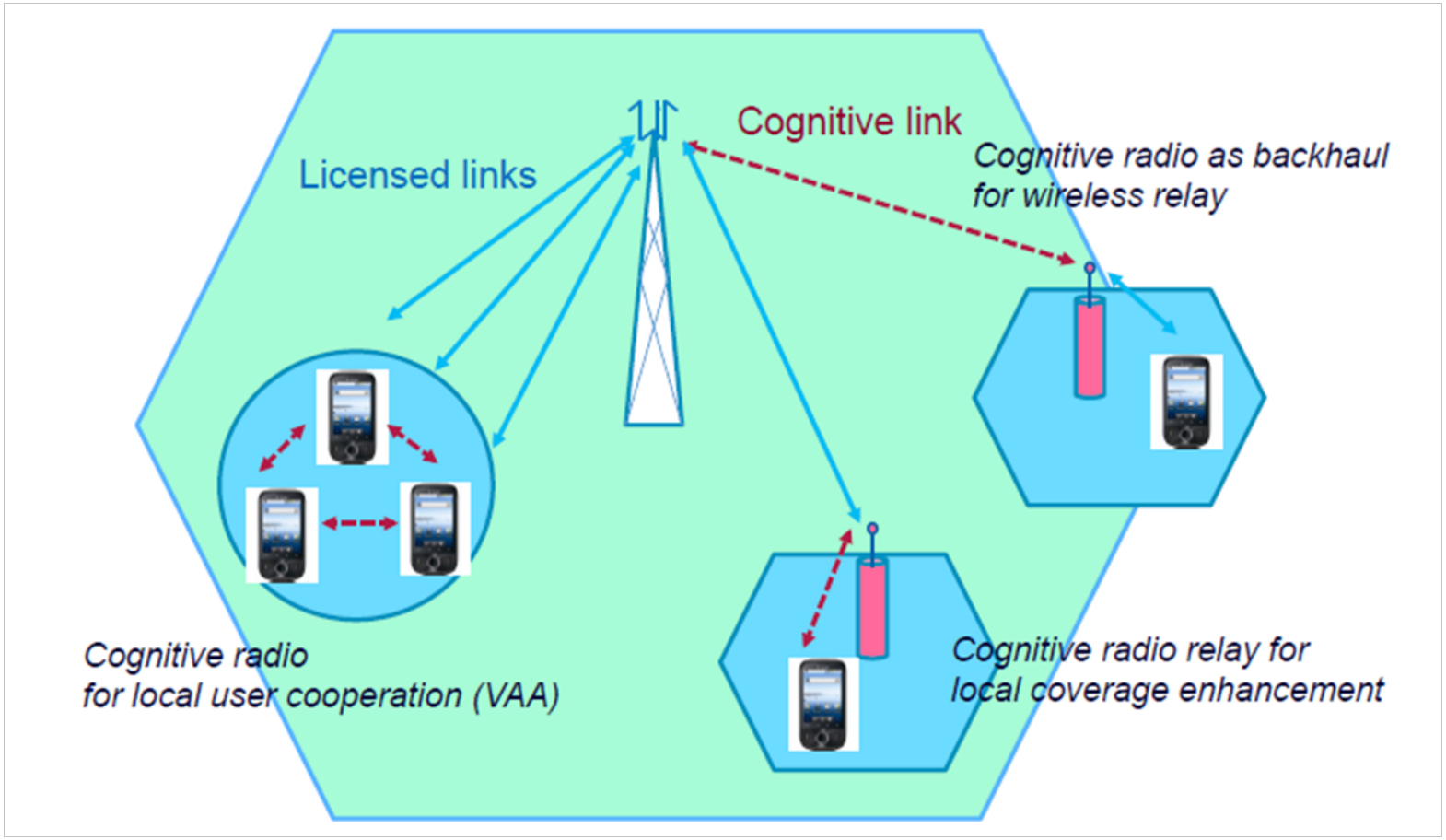
# Non-Cooperative Architecture



# Cooperative Architecture

- Combined used of licensed and CR resources to form a single integrated network
- Using Cooperative communications allow distributed users to process and relay information in a coordinated fashion to achieve significant performance gains.

# Cooperative Architecture



# Major Functional Blocks of Cognitive Radio

| Function | Objective |
|---|---|
| Spectrum sensing | Detection of spectrum holes and estimation of their average power contents. |
| Predictive modeling | Prediction of how long the spectrum hole is likely to remain available for employment by secondary user. |
| Transmit power control | Maximize the data rate of each user subject to power constraints |
| Dynamic spectrum management | Distribute the spectrum holes fairly among secondary users, bearing in mind usage costs. |
| Packet routing | Design a self-organized scheme for routing of packets across the radio network |

# Main in CR issues

**Self Coexistence**

- To avoid secondary users to harmfully interfere with primary users.

**Accurate sensing**

- Sensing aims to determine if a channel is idle or busy in terms of primary user activity.

**Optimized spectrum decision**

- Secondary users are expected to dynamically choose the best available channels and transmission parameters.

**Seamless spectrum handover**

- No latency should be noticed by users during mobility.

# Main in CR issues cont..

**Cross layer design**

- Spectrum sensing is restricted only to the PHY and MAC layers, spectrum management (e.g., spectrum handover, decision making and scheduling) can be related to all upper layers, which makes interaction and coordination between the different layers of the protocol stack necessary.

**Energy efficiency**

- Have limited communication and resource requirements, since most of the devices are battery powered.

# Future Research Directions

- Seamless spectrum handovers
- Proactive spectrum selection and interference avoidance
- Interdependency between the propagation characteristics of radio signals and the frequency band in usage Energy efficiency
- Validation of CR protocols
- Energy efficiency

- Better utilization of frequency band
- Quick and easy information access
- Better connectivity in mobility environment