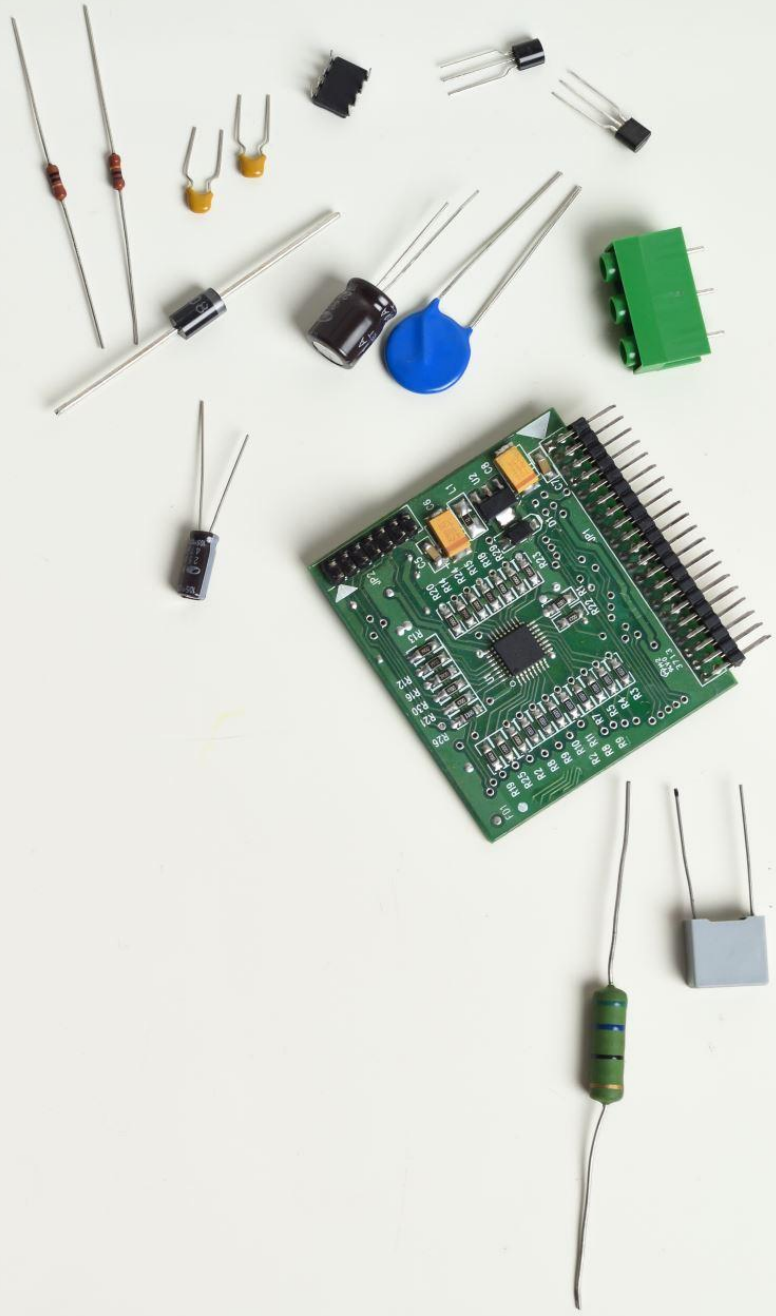


Internet of Things (IoT) Protocols

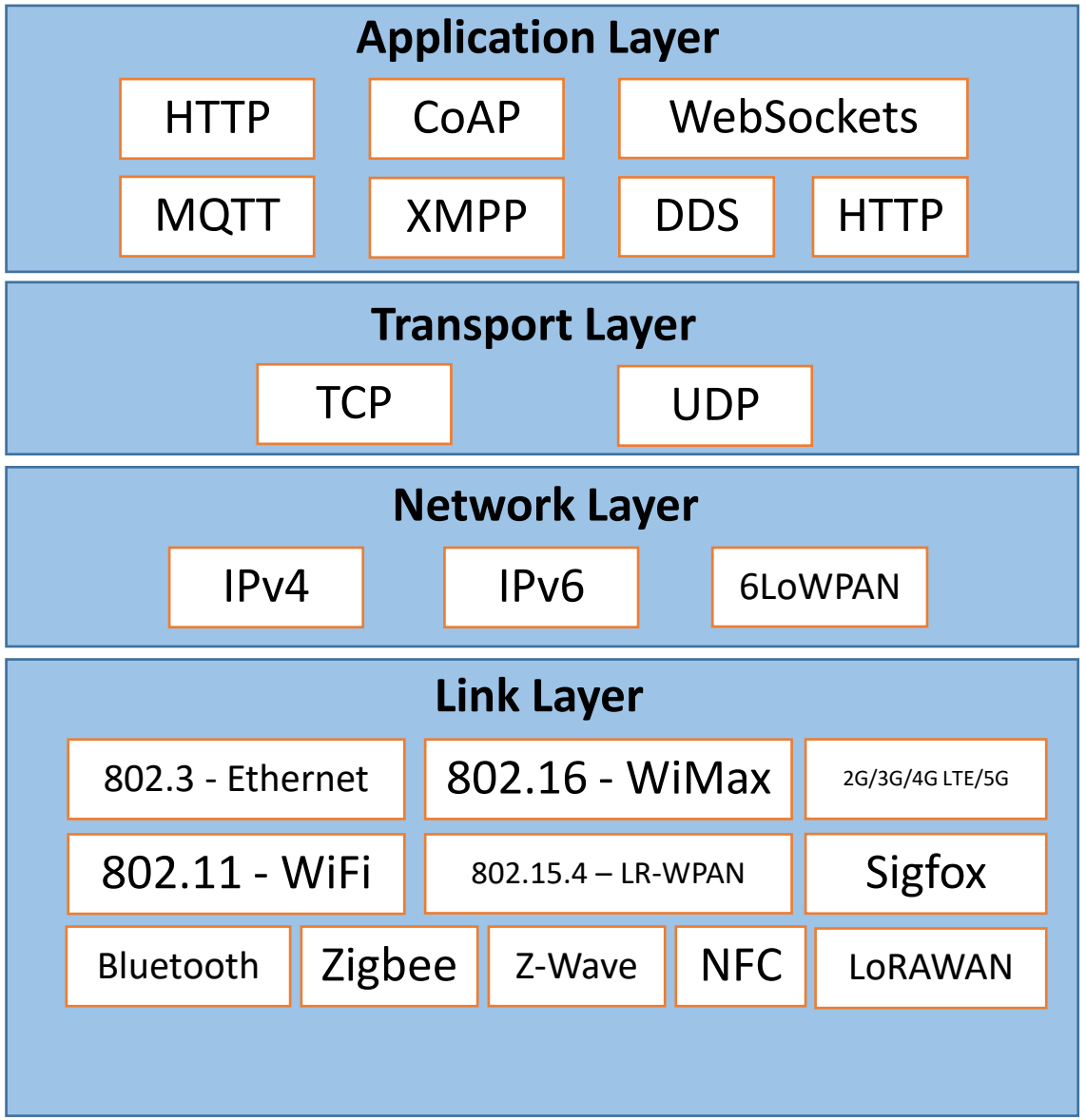
Module Leaders (CSC8112):

Prof. Rajiv Ranjan and Dr. Deepak Puthal

IoT Protocol Stack

ISO/OSI Reference Model	IoT Protocol Stack	TCP/IP Protocol Stack
Application Layer	Applications	Application Layer
	Service Layer (oneM2M, ETSI M2M, OMA, BBF)	
Presentation Layer	Application Protocol Layer (HTTP, CoAP, XMPP, AMQP, MQTT) (NETCONF, SNMP, mDNS, DNS-SD)	
Session Layer		
Transport Layer	Transport Layer (TCP, MPTCP, UDP, DCCP, SCTP) (TLS, DTLS)	Transport Layer
Network Layer	Network Layer (IPv4, IPv6, 6LoWPAN, ND, DHCP, ICMP)	Internet Layer
Data Link Layer	PHY/MAC Layer (3GPP MTC, IEEE 802.11, IEEE 802.15)	Link Layer
Physical Layer		

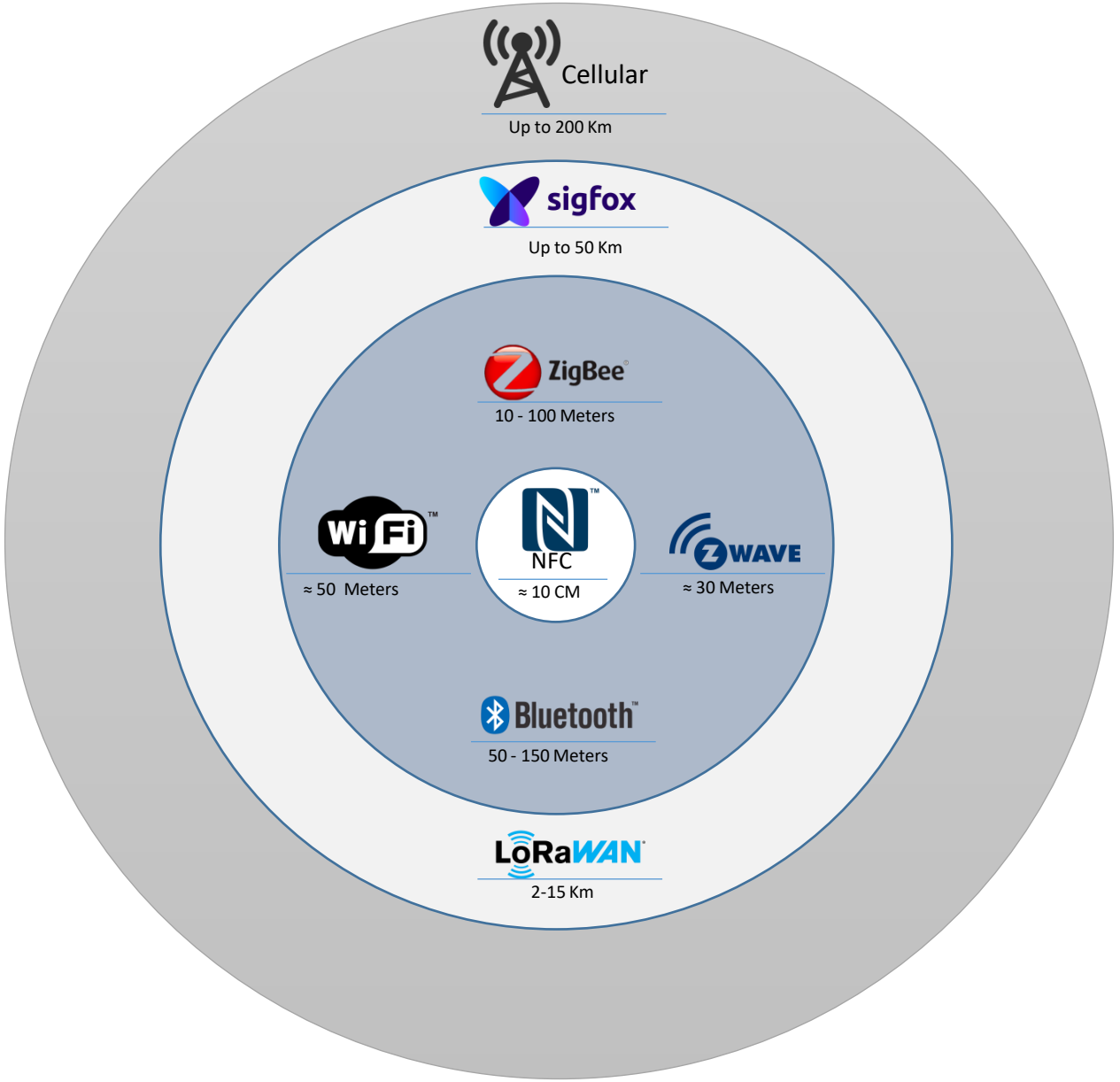
Communication Protocols



Standardization efforts in support of the IoT

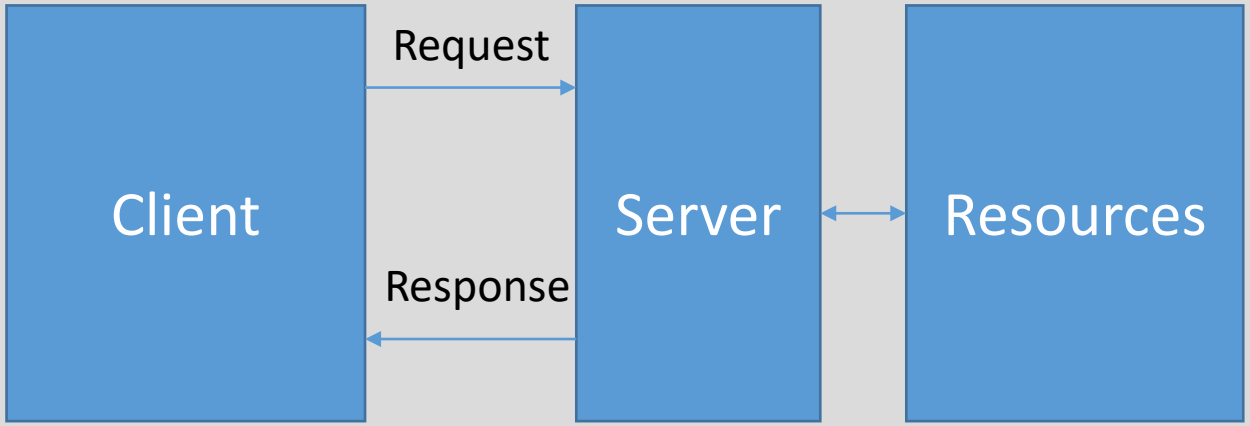
Application Protocol		DDS	CoAP	AMQP	MQTT	MQTT-SN	XMPP	HTTP REST
Service Discovery		mDNS				DNS-SD		
Infrastructure Protocols	Routing Protocol	RPL						
	Network Layer	6LoWPAN				IPv4/IPv6		
	Link Layer	IEEE 802.15.4						
	Physical/ Device Layer	LTE-A	EPCglobal	IEEE 802.15.4	Z-Wave			

IoT Protocols hierarchy



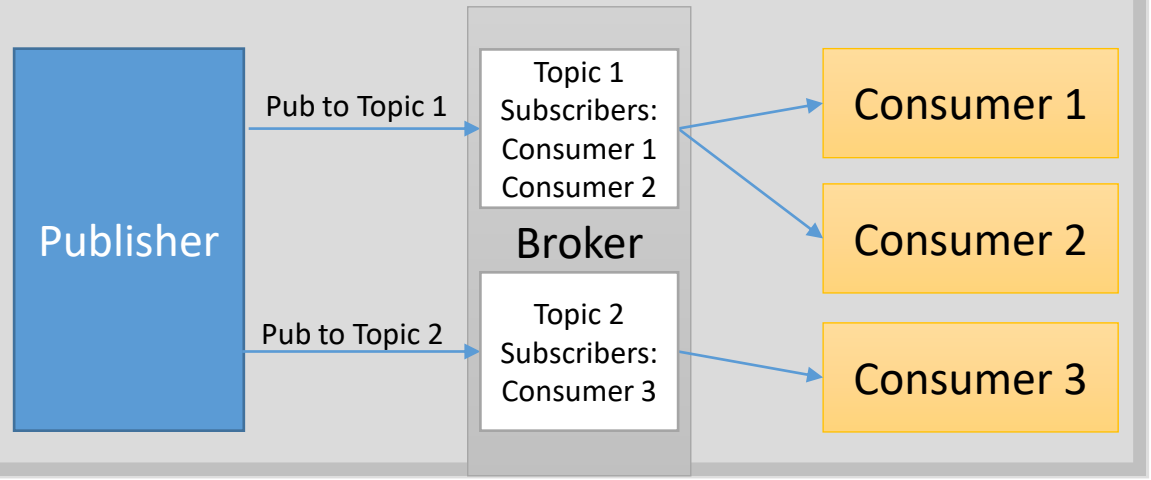
Communication Model

- **Request-Response:** Client sends requests to the server and the server responds to the requests. When the server receives a request, it decides how to respond, fetches the data, retrieves resource representations, prepares the response, and then sends the response to the client.
- Request-Response model is a stateless communication model and each request-response pair is independent of others



Communication Model

- **Publish-Subscribe:** is a communication model that involves publishers, brokers and consumers.
- Publishers are the source of data. Publishers send the data to the topics which are managed by the broker.
- Publishers are not aware of the consumers. Consumers subscribe to the topics which are managed by the broker.
- When the broker receives data for a topic from the publisher, it sends the data to all the subscribed consumers.



Common operating systems used in IoT

Operating System	Language Support	Minimum Memory (KB)	Event-based Programming	Multi-threading	Dynamic Memory
TinyOS	nesC	1	Yes	Partial	Yes
Contiki	C	2	Yes	Yes	Yes
LiteOS	C	4	Yes	Yes	Yes
Riot OS	C/C++	1.5	No	Yes	Yes
Android	Java	-	Yes	Yes	Yes

IEEE 802.11ah

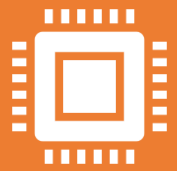
IEEE 802.11 standards are the most commonly used wireless standards. – Wi-Fi

IEEE 802.11ah is a light version of the original IEEE 802.11 wireless medium access standard. – for IoT

The basic 802.11ah MAC layer features include:

- Synchronization Frame
- Efficient Bidirectional Packet Exchange
- Short MAC Frame
- Null Data Packet
- Increased Sleep Time

IEEE 802.15.4



The IEEE 802.15.4 protocol is designed for enabling communication between compact and inexpensive low power embedded devices that need a long battery life.

It defines standards and protocols for the physical and link (MAC) layer of the IP stack.

Transmission requires very little power (maximum one milliwatt),

- 1% of WiFi or cellular networks.
- packet size is limited to 127 bytes
- the rate of communication is limited to 250 kbps

RFID

- The Radio Frequency Identification of RFID works with the help of wireless technology.
- It uses the electromagnetic fields so that it can identify objects.
- The best part of RFID IoT Connectivity Protocols is they do not need any power.
  - The short ranged Radio Frequency Identification is around 10 cm.
  - The long-range Radio Frequency can go up to 200 mm.

Near Field Communication (NFC)

- Near Field Communication (NFC) from the IoT Protocols takes the benefit of safe two-way communication linking.
- NFC IoT Communication Protocols are applicable for the smartphones.
- The essential work of NFC is to expand the “contactless” card technology.
- It works within 4cm (between devices) by enabling the devices for sharing information.

Standard: ISO/IEC 18000-3

Frequency: 13.56MHz (ISM)

Range: 10cm

Data Rates: 100–420kbps

Bluetooth

- One of the broadly used wireless technologies of short-range
- The recently introduced Bluetooth protocol among the **IoT protocols** is BLE (Bluetooth Low-Energy protocol)
  - afford the range of conventional Bluetooth in combined with lower power consumption
- BLE is not designed for transferring large files and will go perfectly with the small portions of data
- The newly invented Bluetooth Core Specification 4.2 adds up one innovative Internet Protocol Support Profile.
- It permits Bluetooth Smart Sensor to get access on the internet straight via 6LoAPAN.

Standard: Bluetooth 4.2 core specification

Frequency: 2.4GHz (ISM)

Range: 50-150m (Smart/BLE)

Data Rates: 1Mbps (Smart/BLE)

Zigbee

- Just like Bluetooth, there is a vast user base of ZigBee.
- ZigBee is designed more for the industrials and less for the consumers.
- ZigBee and the popular ZigBee Remote Control are popular as famed IoT Security Protocols for supplying secure, low-power, scalable solutions along with high node counts.
- The ZigBee 3.0 has taken the protocol to a single standard.
- It made it handier.

Standard: ZigBee 3.0 based on IEEE802.15.4

Frequency: 2.4GHz

Range: 10-100m

Data Rates: 250kbp

WiFi

- For IoT integration, WiFi is a favoured choice
- It has quick data transfer rates along with the aptitude to control a large quantity of data.
- The widespread WiFi standard 802.11 presents you the ability to transfer hundreds of megabits in only one second.
- The only own drawback of this IoT protocol is it can consume excessive power for some of the IoT Application.

  - Standard: Based on 802.11n (most common usage in homes today)
  - Frequencies: 2.4GHz and 5GHz bands
  - Range: Approximately 50m
  - Data Rates: 600 Mbps maximum, but 150-200Mbps is more typical, depending on channel frequency used and number of antennas (latest 802.11-ac standard should offer 500Mbps to 1Gbps)

Long Ranged Wide Area Network (LoRaWAN)

- LoRaWAN is one of the IoT Protocols for the wide area networks.
- LoRaWAN IoT Network Protocols is specifically designed for supporting the vast networks with the help of million low-power devices.
- Smart cities is an application widely used this protocol
- Including the low-cost mobile communication, LoRaWAN is also famed in scores of industries for protected bi-directional communication.

Standard: LoRaWAN

Frequency: Various

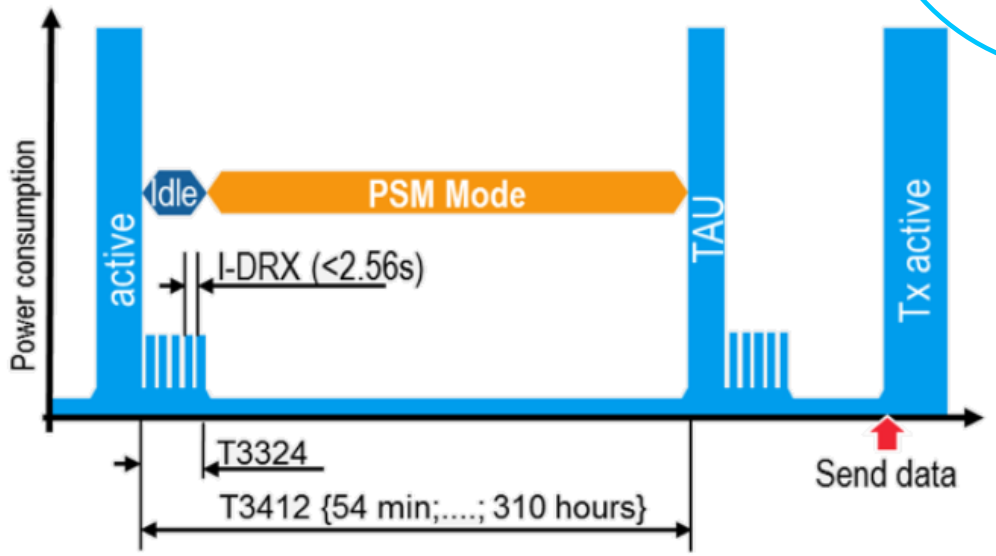
Range: 2-5km (urban environment), 15km (suburban environment)

Data Rates: 0.3-50 kbps.

Narrowband IoT (NB-IoT)

- Low Power Wide Area Network
  - developed by 3GPP
  - subset of the LTE standard
- Focuses specifically on
  - indoor coverage
  - low cost
  - long battery life
  - high connection density

	LTE Cat NB1
3GPP Release	Release 13
Downlink Peak Rate	250 kbit/s
Uplink Peak Rate	250 kbit/s (multi-tone) 20 kbit/s (single-tone)
Latency	1.6s–10s
Number of Antennas	1
Duplex Mode	Half Duplex
Device Receive Bandwidth	180 kHz
Receiver Chains	1 (SISO)
Device Transmit Power	20 / 23 dBm



References

https://ieeexplore.ieee.org/document/7123563

http://downloads.hindawi.com/journals/jece/2017/9324035.pdf