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Smart Device to Device Communication in Internet of Things (IoT) Using 5G Networks: A Review

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Abstract:

In future cellular networks, Device to Device (D2D) communication is foreseen to assume an essential part as it gives super-low latency to consumer communication. This new model will run on both unlicensed and licensed spectrums. It is a progressive expansion of the conventional worldview of cellular communication. D2D organizing is another innovation that gives the 5G network numerous points of interest, for example, remote shared administrations and more prominent ghostly execution. It is additionally assumed as one of the promising methods for 5G remote system administration applications and is utilized in various zones, for example, public wellbeing, dumping network traffic, government-managed retirement public security, social, and gadgets, for example, military applications and gaming. The benefits are expected in form of technical and business challenges that must be addressed before they are integrated into the cellular ecosystem. In current research, various communication technologies in the IoT ecosystem are compared with different requirements, algorithms, and techniques with a brief overview of their architecture. In order to determine the efficacy of different IoT communication technologies, mathematical modeling is also provided with respect to various parameters, such as delay, SNR, and attenuation. This study describes the effectiveness of 5G-enabled smart device communication in the IoT ecosystem in relation to various algorithms, techniques, and mathematical modeling based on a variety of criteria including Standard Power Consumption, Mesh Network, Speed Range and Frequency.

Keywords: D2D Communication, IoT, Wi-Fi, NFC, RFID, Bluetooth Low Energy (BLE), ZigBee, 5G.

Author's Contribution
All authors have Contributed equally.

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Conflict of interest
The authors declare no conflict of interest in publishing this manuscript in IJIST.

Introduction

The Internet of things describes devices with sensors, processing ability, software and other technologies that connect and exchange data with other devices and systems over the Internet over other communications networks [1][2]. IoT could have a couple of potential benefits that offers seamless connectivity. The connectivity technology that is utilized in IoT has less strength consumption, low bandwidth, low processing strength, and seamless conversation with devices in its surroundings because the concept of IoT is processing for anyone, everywhere and for any community. The utility of IoT to domestic appliances e.g., vehicles and others consist of the supply of smart objects which are capable to sense different gadgets and are able to speak and interact with anyone without human interference or intervention [3].

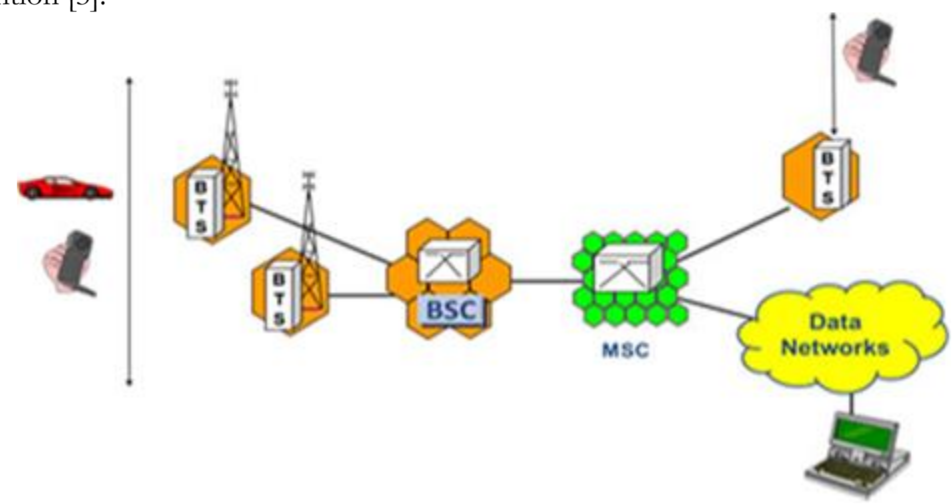

Figure 1. Architecture of Cellular Networks (COAI, 2019)

Communication Technologies Used for IoT

Wi-Fi, NFC, RFID, Bluetooth Low Energy (BLE), ZigBee, and other diverse GSM generations like 1G, 2G, 3G, 4G, and 5G are distinctive IoT technologies based on the size of the network [4].

Table: 1 Different Generations of Cellular Networks

IoT Technology	Standard	Power Consumption	Network Type	Speed	Range	Frequency Spectrum	Mesh
Bluetooth (BLE)	IEEE 802.15.1	10mW	PAN	1 Mbps	50 m	2.4 GHz	No
ZigBee	IEEE 802.15.4	Very Low	PAN	250 Kbps	100 m	2.4 GHz	Yes
Wi-Fi	IEEE 802.11	High	LAN	100-250 Mbps	100 m+	2.4 GHz/ 5 GHz	No
GSM/GPRS	ETSI	Very High	WAN	Moderate	35Km+	850MHz/ 1.9 GHz	No
LTE	3GPP	Very High	WAN	0.1-1 Gbps	28Km/ 10 Km	700-2600MHz	No
5G	5GPP	Very High	WAN	10Gbps	1000 Feet	24.25 GHz	Yes

All of those may be used to relate the shape and the value of the network, whether it's personal, widespread, or neighborhood [5].

Source: Odinma, A.C. 2006. "Next Generation Networks: Whence, Where, and Whither". Pacific Journal of Science and Technology. 7(1):23-30.

D2D Communication

D2D communication is characterized as direct communication between two mobile users without crossing the Base Station (BS) or core network, in cellular networks [6] and cellular communication is accounted as D2D communication [7]. In a traditional cellular network, all communications should be carried out via the BS, even if the contact parties are beyond the limits of proximity-based D2D communication. BS networking is ideal for traditional low-speed mobile networks like voice calls and text messages, where users are rarely close enough for direct contact [8]. D2D communication benefits go beyond spectral efficiency; potentially, it is possible to improve performance, energy efficiency, delay, and fairness. In cellular networks, the figure below indicates D2D Communication [9]. The Cloud Radio Access Network (CRAN) reinforces an adaptable operational framework for 5G networks. A cautious storing technique in D2D correspondence that can enormously upgrade the Quality of Experience (QoE) [10]

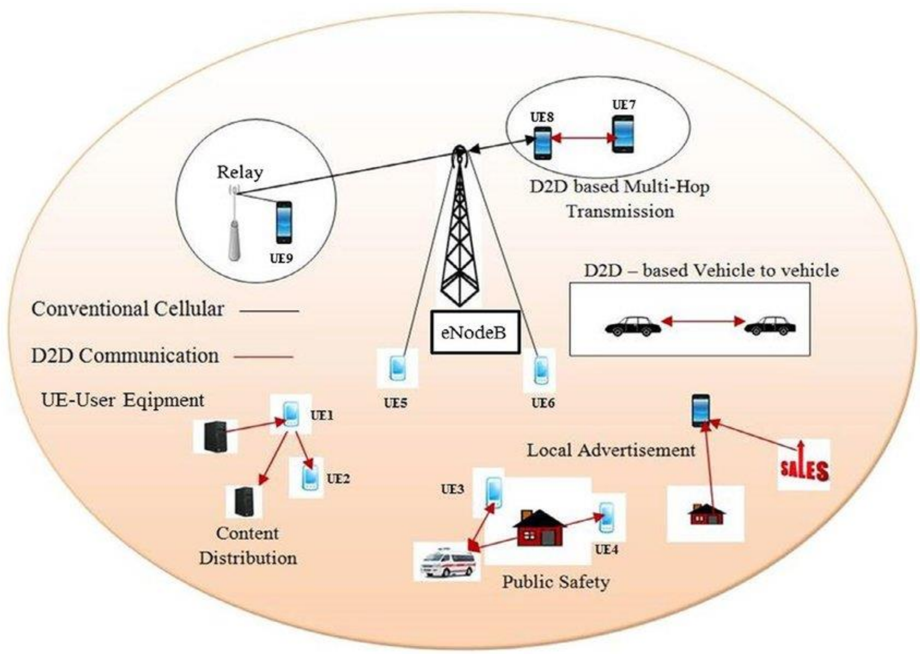

Figure 2. Framework of D2D Communication

Source: Valiveti, H. B., & Polipalli, T. R. (2019). Performance analysis of SLTC-D2D is a mechanism in software-defined networks as per International Journal of Computers and Applications, 41(4), 245-254.

D2D communication permits ultralow dormancy among gadgets and clients that can be taken as an advancing innovation to support the future and an increase in exhibition of the range [11]. The trading of information gatherings by D2D communication associated with all the while under the umbrella of cellular networks is introduced and called the web of things [12]. It takes a shot at both authorized and unlicensed ranges. The most important reason for D2D correspondence is to flexibly a genuine time reaction in IoT [13]. Cell phones and gadgets are developing quickly to shroud the day-by-day human necessities. Huge loads of organizations and enterprises around the planet produce gadgets with various programming and equipment frameworks, and to encourage the correspondence between these gadgets, more examination, and recommendations of the most recent conventions may require giving full similarity between different gadgets during a customary cellular organization. Gadgets inside the endorsed cell range aren't permitted to talk straightforwardly with each other, and each correspondence happen through the base stations [14].

D2DCommunication in IoT Using 5G Networks

In a standard cellular system, the permitted cellular bandwidth and all devices are not permitted to communicate directly with one another via the base stations [15]. Device terminal relaying allows computers in a network to support each other as transmission relays and to implement an immense ad hoc mesh network [16]. A two-tier 5G Cellular network with two tiers of macrocell and device tiers is envisioned in this article [17]. Two-tier cellular networks are given which includes a macrocell tier and a device tier. Four standard sorts of Tier correspondence are portrayed in this article that include 1) Devices moving with manager-controlled association establishment (DR-OC), 2) Direct D2D correspondence with overseer-controlled association establishment (DC-OC), 3) Device giving off with device-controlled association establishment (DR-DC), and 4) Direct D2D correspondence with device controlled association establishment (DC-DC) [18].

A few attributes of device communications that are utilized as a component for the up-and-coming 5G networks in IoT are given in this article with High Data Rate or Low Latency, Aggregation, and Coverage Extension, Low Energy Consumption Communication, sight and sound IoT, and Multicast [19]. The vicinity-based administrations are the greatest security hazard for D2D Communication. Future work for sheltered device communication is to present some better safety efforts for the protected correspondence between gadgets associated with 5G organizations [20].

Mobility Management in D2DCommunication Using 5G

Like various remote communications systems, D2D communication mobility management is a critical test that can still not seem to be thoroughly investigated [21]. A proposed model is likewise introduced to comprehend the issue of mobility management in D2D communication [22]. Mobility management in gadget-to-gadget correspondence is a key test that is yet to be developed [23]. The principle thought depends on TDD Configuration from the recently distributed paper [24]. For the legitimacy of the proposed model the reproduction results are given in this paper without versatility. Portability Management of any remote correspondences was viewed as a high-need [25].

Intelligent D2D Communication

To accomplish intelligent D2D communication in the environment of IoT, various communication algorithms or protocols have been introduced [26]. These algorithms include (a) Probabilistic Algorithm, (b) Bioinspired Algorithm, (c) Hierarchal Algorithm, and (d) Context-aware Aware Algorithm. The principal reason for this investigation is the means by which Intelligent D2D communication ought to be accomplished by utilizing diverse cutting-edge directing calculations [27]. These frameworks can work exclusively and coordinate the assortment, trade, and transmission of data in a multipurpose way without unified control. Specialized gadgets are expanding each day, so by increment in the number of gadgets correspond to slacks are likewise to happen like the speed of the correspondence, memory being utilized and battery utilization [28].

Devices in D2D communication

Several devices and technologies have are a part of D2D communication. Here are some examples:

Smartphones:

Smartphones are commonly used for D2D communication, especially in scenarios like file sharing, messaging, and collaborative applications. For example, features like Bluetooth, Wi-Fi Direct, and Near Field Communication (NFC) allow smartphones to communicate directly with other nearby devices.

IoT Devices: Internet of Things (IoT) devices, such as smart home devices (smart thermostats, smart speakers, etc.), wearables (smartwatches, fitness trackers), and industrial sensors, can engage in D2D communication for local data exchange and coordination.

Vehicular Communication:

Vehicles equipped with vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication technologies can participate in D2D communication for improved road safety, traffic management and coordination.

Wireless Ad Hoc Networks:

In wireless ad hoc networks, devices can form temporary networks and communicate directly with each other without the need for a fixed infrastructure. This is often used in military, disaster recovery, and other scenarios where a traditional network is unavailable.

Mesh Networks:

Mesh networks consist of interconnected devices that relay data, enabling D2D communication within the network. This approach is useful in scenarios where coverage needs to be extended or where traditional network infrastructure is limited.

P2P File Sharing:

Peer-to-peer (P2P) file-sharing applications enable devices to share files directly with each other over the internet without going through a centralized server. Examples include BitTorrent and various decentralized file-sharing protocols.

Proximity-based Services

Devices can communicate directly when they are in close proximity to each other. This is used in location-based services, interactive marketing, and other context-aware applications.

Emergency Communication:

In disaster-stricken areas or situations where traditional communication networks are compromised, D2D communication can be used to establish local communication between devices.

Drones and Robotics:

Drones and robotic devices can communicate with each other directly for collaborative tasks, swarm behavior, and coordinated actions. It's important to note that the list above is not exhaustive and is continually evolving with new devices and technologies being developed. The specific devices that participate in D2D communication can vary depending on the use case and technological advancements.

Analysis of Different Communication Technologies:

IoT links a variety of devices to a network that exchanges information easily, exchanging data that allows humans and machines to communicate with each other freely [29]. It combines Bluetooth wireless networking, Wi-Fi, 5 G networks, and wired links such as Ethernet cables. So, IoT devices are installed with a wide range of capabilities. CoAP, DTLS, and MQTT, among others, provide communications protocols. IPv6, LPWAN, Zigbee, Bluetooth Low Energy, Z-Wave, RFID, and NFC are wireless protocols [30]. This study uses qualitative analysis design to analyze the quality of connected IoT devices using 5G [31]. D2Dcommunication has two main applications in licensed and unlicensed spectrums. In IoT, various devices communicate through different communication technologies like NFC, RFID, WiMAX, Bluetooth, Zigbee, or other communication technologies. By connecting these devices various issues occur like signal attenuation, delay, and bandwidth issues [32]. In the present study, communication technologies i.e. Bluetooth, Zigbee, and RFID in the environment of IoT connected through 5 G analyzed and compared, on the basis of their architecture and various parameters like SNR (Signal to Noise Ratio), Signal Attenuation, Throughput and Delay, using mathematical modeling [33].

Bluetooth

Bluetooth technology is a de-facto Wireless Personal Area Network (WPAN) standard. The WPAN is an ad-hoc network of linked devices within a radius of 10 m. Bluetooth Special Interest Group (SIG) published Bluetooth. IEEE 802.15 characteristics. Bluetooth was developed for mobile devices, laptops, tablets, and others to be used as phones, headers, and wearable devices (like smart Watches, and smart Shoes) [32].

Architecture of the Bluetooth is based on two types of networks 1) PICONET and the 2) other is SCATERNET [34]. The fundamental architecture of the Bluetooth is shown in the figure.

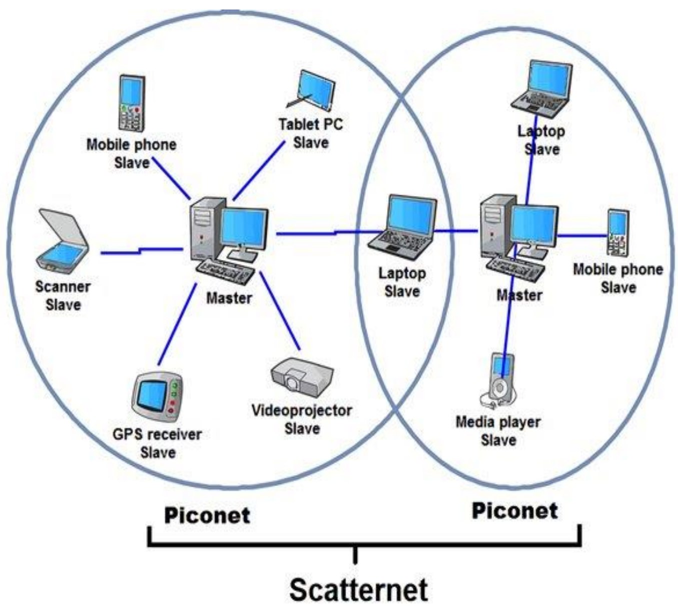

Figure 3. Bluetooth SCATTERNET Architecture

Source: Zanaj, E., Caso, G., De Nardis, L., Mohammad pour, A., Alay, Ö, & Di Benedetto, M. G. (2021). Energy efficiency in short and wide-area IoT technologies—A survey. Technologies, 9(1), 22.

The Efficient Cycle Algorithm for Bluetooth

The set of rules for the Efficient Double Cycle (EDC) is based primarily on essential ideas: first, it is essential to avoid NULL transmissions closer to and from the slaves; secondly, the normal equity of a Round Robin scheme should be maintained. These objectives will be achieved if the selection of the slave to be polled takes into account the master's expertise of occupancy of quarters queues [35]. Algorithms for multipath routing

1. begin
2. if (Cycle_End = = False) then
3. if (Curr_Cycle == Up) then goto Up − Cycle;
4. else goto D_W − Cycle;
5. if (Cycle_ End == True) then
6. if (Curr_Cycle == Up) then
7. begin
8. Cycle − End = False;
9. Curr − Cycle = D_W;
10. < Update E(D_W) >;
11. goto D_W − Cycle;
12. end
13. else

```
begin
for( i = 1; i <= N; i + +)
 do c_i = max{0, (c_i − 1)};
  Curr − Cycle = Up;
  < update E(UP) >;
 goto Up_Cycle;
 end
```

Zigbee Network

Zigbee is the latest Wireless Personal Area Network (WPAN) standard established based on IEEE 802.15.4 which is low cost, low power consumption, self-operation, short distance, low complexity, and many more are the primary features of the Zigbee network. Zigbee is usually used in the construction of automatic control, automation of industry, and other fields such as households and hospitals. Devices from Zigbee create divergent networks. These networks are (a) star topology, (b) cluster tree topology, and (c) mesh networks.[36].

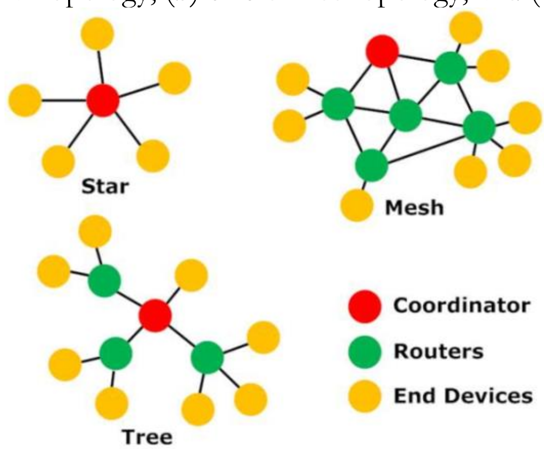

Figure 4. Zigbee Network Topology

Source: Salih, M. A. A. A. M. (2012). Design and performance analysis of building monitoring system with wireless sensor networks. Iraqi Journal of Science, 53(4), 1097-1102.

Cluster Tree Zigbee Algorithm:

In a cluster tree algorithm, each packet node evaluates the next jump related to the node address. The subsequent address for the routing node is denoted as A, and the depth is represented by d, following the specified formula.

$$A < D < A + Cskip(d - 1)$$

Where $Cskip(d)$ is a calculation function?

If the selected node is the successor of the receiver node, the further jump address is N:

$$N = D$$

If there is a terminal,

$$D > A + R_m * Cskip(d)$$

Else

$$A + 1 + \left[\frac{D - (A + 1)}{Cskip(d)}\right] \times Cskip(d)$$

If the selected node is not the successor of the receiver node, the father node receives the packet node.

AODVjr algorithm:

This algorithm also deletes routing errors. It can prevent circulation problems and invalid RREP packets. Hello packets are also deleted to get rid of the transmission types.

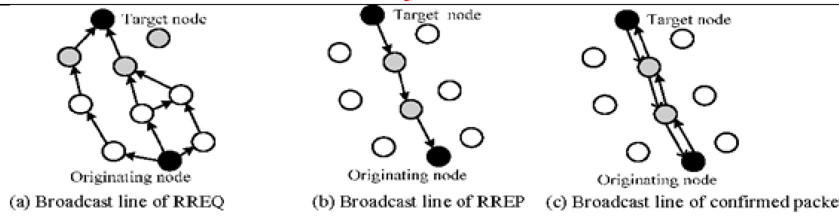

Figure 5. Pattern for AODVjr Algorithm for Searching And Communicating

Source: Li, J., Zhu, X., Tang, N., & Sui, J. (2010, July). Study on ZigBee network architecture and routing algorithm. In 2010 2nd International Conference on Signal Processing Systems

WIFI Network:

The structure of the WiFi community includes a hard and fast of APs (Access Point) or includes one or more APs and one or more clients. One patron is without delay connected to the only AP. The AP communicates with the patron through disseminate the Service Set Identifier (SSID) or community call via way of means of packets called beacons.

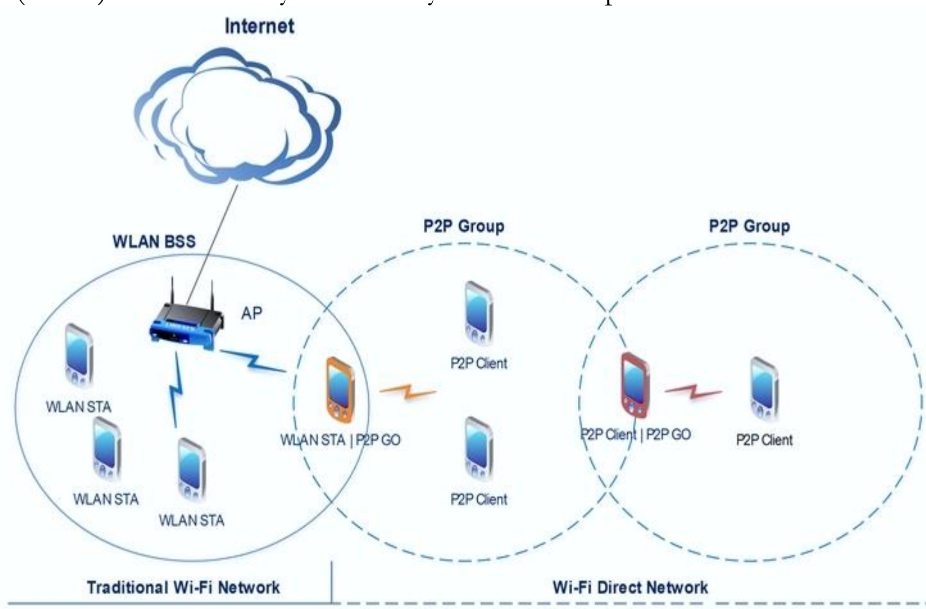

Figure 6. WiFi Network Architecture

Source: Khan, M. A., Cherif, W., Filali, F., & Hamila, R. (2017). Wi-Fi direct research-current status and future perspectives. Journal of Network and Computer Applications, 93, 245-258.

For connectivity or use in internet services, the WiFi network utilizes radio signals to provide access to the internet or the mobile operator network. It only offers services up to the level of the connection layer and therefore relies on the wired IP network for end-to-end connectivity. The NAPT Gateway provides access to other IP-based networks as seen in the figure, while the AAA server proxy manages access and authentication of mobile terminals. WiFi employs a Remote Authentication Dial (RADIUS) protocol along with an Extensible Authentication Protocol (EAP) to authenticate a terminal attempting to connect to the network. Each Access Point (AP) in a WiFi network has a limited range that connects the client to it. The actual distance varies depending on the environment, whether the client is situated indoors or outdoors.

Table 2: Different Standards of IEEE 802.11

Technologies	Indoor/Outdoor	Bitrate	Frequency Bands	License	Bandwidth	Modulation	MIMO
IEEE 802.11	20m/100m	2 Mbps	2.4Ghz	Unlicensed	20Mhz	FHSS and DSSS	

IEEE 802.11b	35m/140m	11Mbps	2.4Ghz	Unlicensed	20Mhz	HR-DSSS	
IEEE 802.11a	35m/19m	54 Mbps	5Ghz	Unlicensed	20Mhz	OFDM	
IEEE 802.11g	45m/90m	54 Mbps	2.4Ghz	Unlicensed	22Mhz	OFDM/DSSS /CCK	
IEEE 802.11n	70m/250m	600 Mbps	2.4Ghz/5Ghz	Unlicensed	20Mhz/40 Mhz	OFDM	4X4

Source: http://bucarotechelp.com/networking/standards/81090201.asp

RFID Architecture:

RFID is an automated non-contact detection technology for accessing relevant data through automatic target recognition of the RF signal. Until RFID is completely perceived, it is imperative to see how radio frequency correspondence happens. By creating a special electromagnetic wave impact at the source, the beneficiary can be seen a long way from the source, which at that point distinguishes it and thus the data. The RFID label comprises a receiving wire, a remote transducer, and an epitomizing film. A radio wire, handset, and decoder is an RFID peruser that conveys occasional signs to ask about any close by tag. RFID frameworks can likewise be recognized based on the recurrence range they use. The standard ranges are low frequency (LF: 125-134.2 kHz and 140-148.5 kHz), high frequency (HF: 13.56 MHz), and ultra-high frequency (UHF: 868 MHz-928 MHz), suggesting that the architecture is based on one of the other types of auto-ID systems, such as auto-ID optical barcode systems. Barcodes supply product information through bars of varying width and space between them. Using a barcode reader, also called a scanner, the barcode of the product is captured to interpret the data for a specific product. In this instance, the reader is directly linked to the cash register.

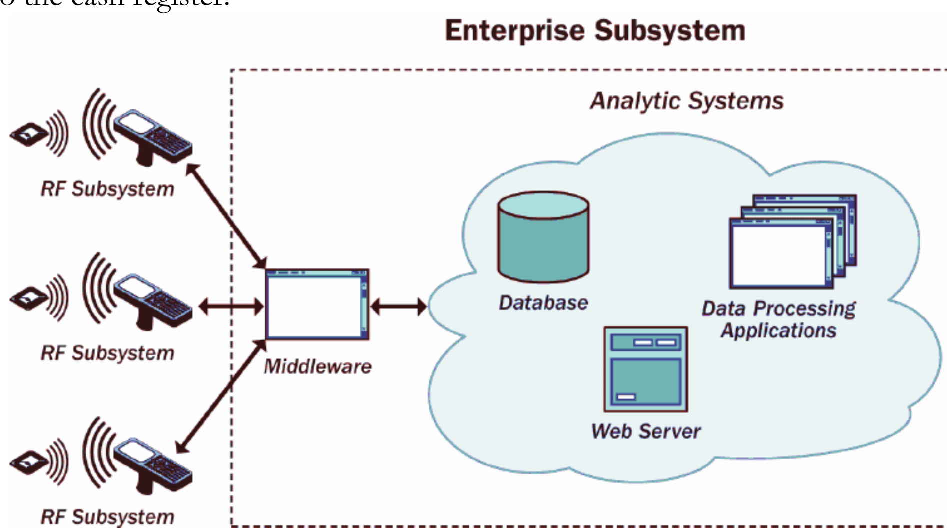

Figure 7. RFID Architecture

Source: Kolarovszki, P., & Vaculík, J. (2014). Intelligent storage system based on automatic identification. Transport and Telecommunication Journal, 15(3), 185-195.

Network Architecture of D2D Communication

The architectural design of D2D network include components which are divided into local network, network management, and D2D applications. The local D2D network contains a wide variety of devices and communicates through direct contact. After they have been integrated into the network architecture, aggregators collect information from all D2D devices and link it to the main network. This information will be sent to the gateway which connects to the access network. The linking of network may be thorough wired or wireless.

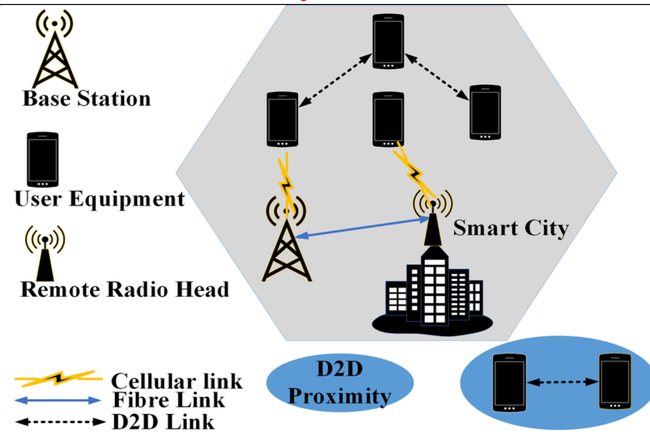

Figure 8. 5G Enabled D2D Communication Network Architecture

Source: Edris, E. K. K., Aiash, M., & Loo, J. (2019, August). Investigating network services abstraction in 5G enabled D2D communications. (SmartWorld/SCALCOM/UIC/ATC/CBDCom/IOP/SCI) (pp. 1660-1665). IEEE.

D2DCommunication Types

On the basis of spectrum allocation D2D communication is further categorized into 2 types 1) Inband and 2) outband.

In band D2D Communication

Mobile communication and D2D communication are licensed by the same set of mobile operators. For D2D and cellular contact respectively (overlay), the licensed spectrum may be divided into non-overlapping portions or may not be subdivided at all (underlay). It is simpler to enforce the overlay scheme, but the underlay scheme leads to an opportunistic and therefore more efficient use of spectrum and improved operator income.

Out band D2D Communication

D2D communication uses unlicensed spectrum where cellular communication does not occur (e.g. the free 2.4 GHz ISM band or the GHz mm-Wave band). Although interference from other electronic devices (such as Bluetooth and Wi-Fi) operating in this band is still present, this helps to minimize interference between D2D and cellular users. When using a licensed spectrum, operators can control interference, but this is not feasible for the outbound scheme.

5G Network Architecture

The All-IP-based stage for Wireless and Mobile Network Interface Networking is found in the organization design proposed by a structure model for portable 5 G organizations. The PC consists of a client terminal (which assumes a basic part in the new engineering) and various free, independent advancements for radio access. Every innovation for radio access is utilized as an IP association with Internet's outside world. In any scenario, there will be independent radio interfaces for each Remote Access Technology (RAT) in the portable terminal e.g., we need admittance to four unique RATs, to make these engineering practices, we have to give four distinctive access interfaces in the versatile terminal and have them all dynamic. Radio access developments with basically QoS maintain parts that give Internet access and are portrayed in the underlying two levels of OSI (data interface level and real level) which is dependant upon the establishment of radio access (for instance 3 G and WiMAX have strong QoS maintenance, yet WLAN doesn't). The association layer is over the OSI-1 and OSI-2 layers, and in the current frameworks organization world, either IPv4 or IPv6, paying little brain to radio access propels, this layer is IP (Internet Protocol). Bundle guiding should be finished according to set-up customer methodologies. The action of the immaculate stages inside the current show stack, which shape the proposed design, is presented in Figure 10:

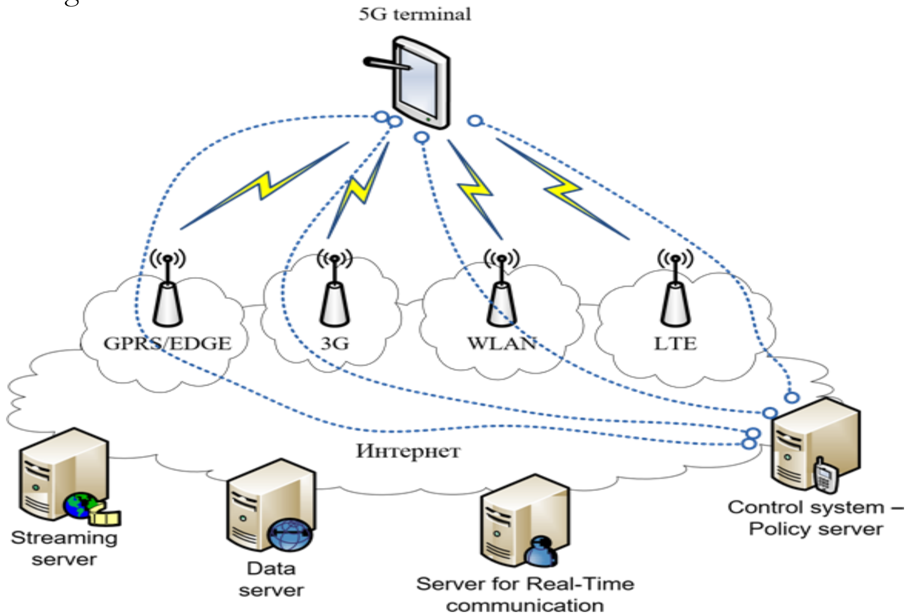

Figure 9. Mobile Network Architecture of 5G

Source: Tudzarov, A., & Janevski, T. (2011). Design for 5G mobile network architecture. International Journal of Communication Networks and Information Security, 3(2), 112-123.

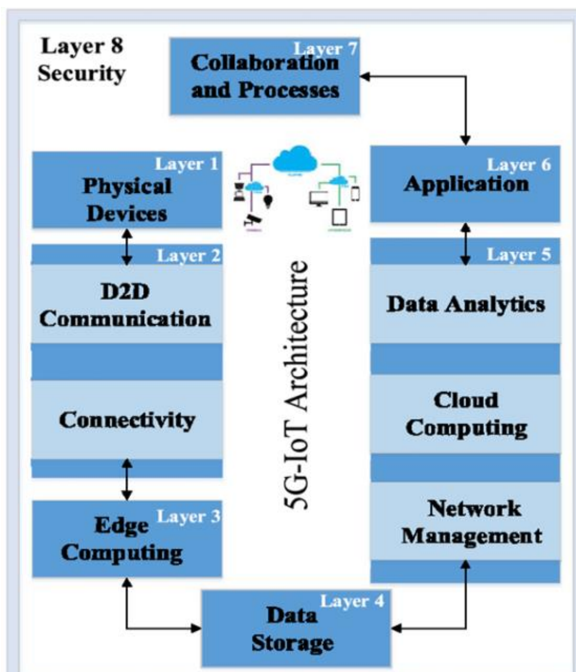

Figure 10. Protocol Layout for the Proposed Architecture

Source: Meenal G. Kachhavay et al, International Journal of Computer Science and Mobile Computing, Vol.3 Issue.3, March- 2014, pg. 1080-1087

5 G-based IoT Architecture

The 5 G-based IoT Architecture is expected to provide applications with all of the wireless, reconfigurable, and social interfaces available on demand in real-time. 5 G-based IoT Architecture provides the following:

- Provide logically separate networks to fulfill the needs of submissions

- Using cloud-based radio access network (Cloud RAN) to restore Radio Access Network (RAN) to have huge multiple connections standards and enforce RAN functions on-demand 5 G Needed.
- Simplify main network architecture to enforce network feature configuration on demand.

- **Table 3:** A Descriptive Comparison of Different IoT Architecture

Architecture/Criteria	Low Latency	Robustness of connection	Support of Different Data Types	Reconfigurability	Wide Coverage
Three level Architecture	No	No	No	No	No
SDN Architecture	No	Yes	No	Yes	No
QoS Architecture	No	Yes	No	Yes	No
*SoA Based Architecture	No	No	No	Yes	No
IoT-A- Architecture	Yes	Yes	No	No	Yes
S-IoT Based Architecture	No	Yes	No	No	No
The Proposed Architecture	Yes	Yes	Yes	Yes	Yes

- **Source**: Al Harbi, S., Halabi, T., & Bellaiche, M. (2020, December). Fog computing security assessment for device authentication in the Internet of things.

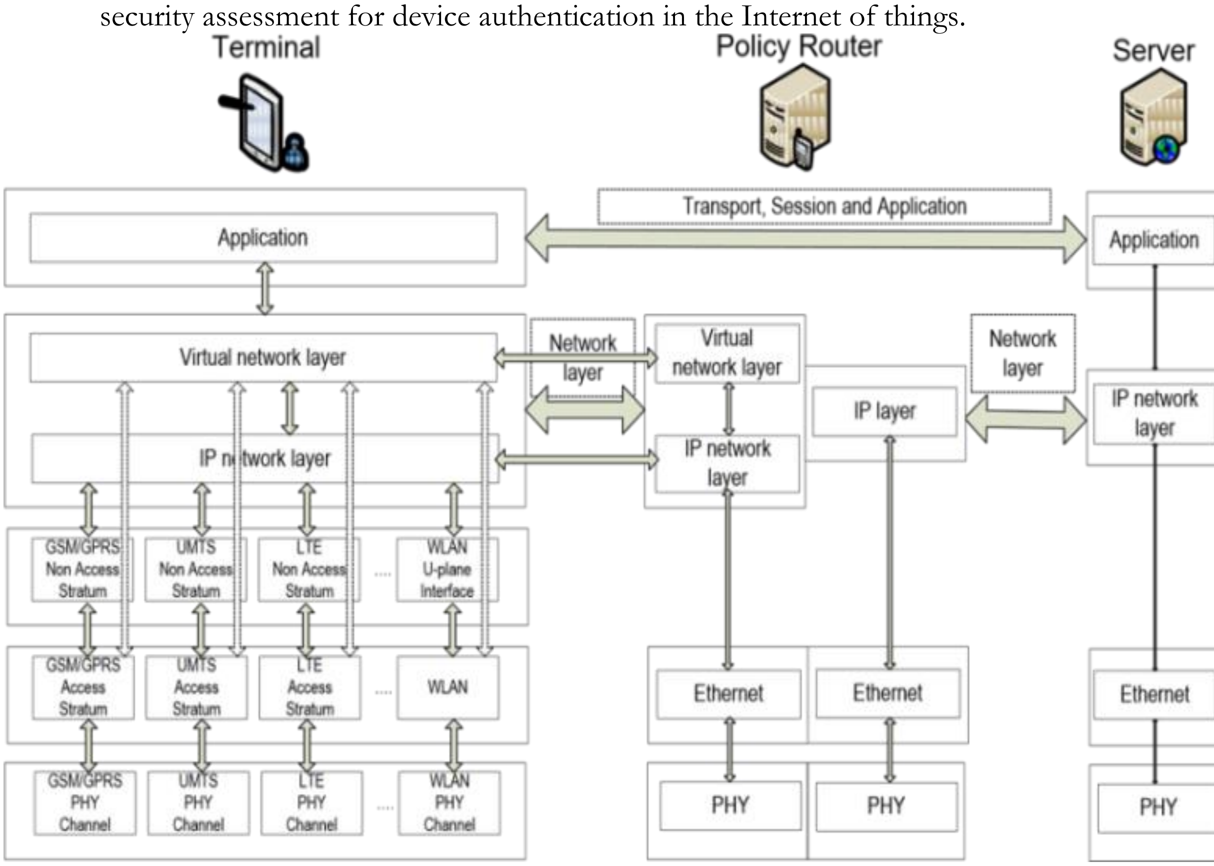

Figure 11. 5G IoT Architecture

Source: Rahimi, H., Zibaeenejad, A., & Safavi, A. A. (2018, November). A novel IoT architecture based on 5G-IoT and next-generation technologies.

Analyzing the quality of smart devices in D2D communication involves assessing various performance metrics to ensure reliable and efficient communication. Here are some algorithms and techniques commonly used for this purpose:

Signal Strength and Link Quality Analysis:

Received Signal Strength Indicator (RSSI): Measures the strength of the received signal to estimate the distance between devices.

Signal-to-Noise Ratio (SNR): Compares the strength of the received signal to the background noise, indicating the quality of the communication link.

Bit Error Rate (BER): Calculates the ratio of incorrectly received bits to the total transmitted bits, providing insight into data transmission accuracy.

Packet Loss and Latency Analysis:

Round-Trip Time (RTT): Measures the time taken for a packet to travel from the source device to the destination device and back. Elevated RTT indicates latency in the communication. Packet Loss Rate: Measures the proportion of packets lost during transmission, highlighting communication reliability issues. Jitter Analysis: Assesses the variability in packet arrival times, which can impact the consistency of communication.

Network Topology and Routing Algorithms:

Distance Vector Routing: Calculates routes based on the distances between devices, helping to optimize communication paths. Link-State Routing: Uses comprehensive knowledge of the network's current state to determine the best paths for communication. Dynamic Source Routing (DSR): Establishes routes based on information collected from previous communications between devices.

Congestion Control and Load Balancing:

Quality of Service (QoS) Algorithms: Prioritizes specific traffic types to ensure reliable and timely delivery of critical data. Load Balancing: Distributes communication traffic evenly across available paths, preventing network congestion and enhancing overall performance.

Energy Efficiency Algorithms:

Sleep Scheduling: Determines when devices can enter sleep mode to conserve energy while maintaining communication capabilities. Power Control: Adjusts transmission power levels based on the proximity of devices, minimizing energy consumption.

Channel Allocation Algorithms:

Frequency Hopping Spread Spectrum (FHSS): Distributes communication across multiple frequency channels to reduce interference and improve reliability. Time Division Multiple Access (TDMA): Divides communication time into time slots for different devices, minimizing collisions and improving efficiency.

Security and Authentication:

Public Key Infrastructure (PKI): Uses asymmetric cryptography for secure device identification and communication. Authentication Protocols: Verify the identity of devices before allowing communication to prevent unauthorized access.

Machine Learning Algorithms:

Anomaly Detection: Uses machine learning models to identify unusual patterns in communication behavior, indicating potential issues or threats. Predictive Analytics: Utilizes historical data to predict communication quality and identify potential future problems. These algorithms and techniques collectively help in assessing the quality of D2D communication in smart devices, ensuring smooth and reliable operation in various applications such as the IoT and smart homes.

D2D Performance

Applying D2D technology to 5G can enhance signal/data transfer efficiency in a number of ways. A device cannot communicate using the base station if the Signal Interference plus Noise Ratio (SINR) is low and the device is outside the range of the base station. However, this can be resolved by relaying signals from devices that still receive signals from the base station, in accordance with the D2D working principle.

Bluetooth BLE

Bluetooth BLE works at the speed of 1Mbps within a range of 50m having standard IEEE 802.15.1. The actual power consumption of Bluetooth is 10 mW. Bluetooth works on the spectrum of 2.4GHz having network type PAN (Personal Area Network). To compute the time required for sending a specific number of client information bytes, we need to consider the discontinuity and the bundle overhead added by every convention layer, without retransmission, this time can be determined as:

$$t_R(N_U . t_{ACK}(L_R + O_R(L_R) + H_L) + t_{TX}(L_{ff}(N_U) + O_R(L_{ff}(N_U)) + H_L$$

- Where N_U are data bytes by the number of users,
- Where L_R Is the maximum number of RFCOMM frames? Size value constrained by two limits RFCOMM maximum frame size N_1 and L2CAP maximum transfer unit for RFCOMM M_R.

$$L_R = \min(N_1, M_R - O_R(N_1))$$

Where $O_R(x)$ is overhead introduced by RFCOMM. 5 or 4 bytes depending if the data size is higher than 127 bytes. Where H_L is the size of the L2CAP header having 4 bytes and $n_{if}(N_U)$ are the numbers of non-final RFCOMM frames used to move the user bytesN_U. These numbers are computed in the following way.

$$n_{ffn}(N_U) = [\frac{N_U}{L_R}]$$

Where [x] is the lowest integer.

- The last RFCOMM frame data bytes are $L_{ff}(N_U)$, these are also calculable form N_U and L_R.

$$L_{ff}(N_U = ((N_U - 1) \bmod L_R) + 1$$

- $t_{ACK}(X)$: The delay needed for the transmission and identification of the first and intermediate RFCOMM frames correspond to all Baseband BT packets. All one-slot packets(ACK) that must be sent by the receiver to identify each received packet have to be computed by the variable using a recursive operation, the term $t_{ACK}(x)$ can be determined.

$$t_{ACK}(x) = \begin{Bmatrix} \begin{cases} 0 & x = 0 \\ 2.T_s & 0 < x \le L_{1s} \\ 4.T_s & L_{1s} < x \le L_{3s} \\ 6.T_s & L_{3s} < x \le L_{5s} \\ 6.T_s.\left\lfloor \frac{x}{L_{5s}} \right\rfloor + t_{ACK}(x \bmod L_5) & x > L_{5s} \end{cases} \end{Bmatrix}$$

The operator $\lfloor x \rfloor$ represents the highest integer lower than x, T_s determines the length of the BT slot ($625\ \mu s$), while L_{1s}, L_{3s} and L_{5s} are the sizes of the maximum payload 1, 3, and 5 slot-BT packets including DM-type packets 17, 21, and 224 bytes respectively. Packets with a higher limit are picked. Thus L_{1s}, L_{3s} and L_{5s} correspond to $L^H_{3,1}, L^H_{3,3}$ and $L^H_{3,5}$.

Where $t_{TX}(x)$ Defines the time for transmission of the final RFCOMM frame (x bytes). This term does not add the final acknowledgment to slot of the last BT packet as the receipt of user data ends until the last bit of the final frame arrives at the receiver, only taking into account the time taken to convey the bytes in the last frame. Again this delay in transmission is essentially based on the type and rate of the packet used. We've got that for the DM-type.

$$t^M_{TX}(x) = \begin{Bmatrix} 0 & x = 0 \\ d_1(x) & 0 < x \le L^M_5 \\ t^M_{TX}(x \bmod L^M_5) + t_{ACK}(L^M_5 \lfloor x/L^M_5 \rfloor & x > L^M_5 \end{Bmatrix}$$

Where the time needed to transmit is $d_1(x)$, specified in, with a data payload of x bytes at a fundamental rate of 1Mbps, a BT packet. As in the case of t_{ACK}, this word for t_{TX} also involves the segmentation that is done if the concluding L2CAP frame requires more than one

DM5 packet (which occurs if $x > L_5^M$). The identification slots of the corresponding intermediate 5-slot BT packets are thus also calculated.

Assuming these criteria, the term $t_{TX}(x)$ for DH packets can be computed as follows:

$$t_{TX}(x) = \begin{cases} 0 & x = 0 \\ d_2(x) & 0 < x \le L_{2,1}^H \\ d_3(x) & L_{2,1}^H < x \le L_{3,1}^H \\ d_2(x) & L_{3,1}^H < x \le L_{2,3}^H \\ d_3(x) & L_{2,3}^H < x \le L_{3,3}^H \\ d_2(x) & L_{3,3}^H < x \le L_{2,5}^H \\ d_3(x) & L_{2,5}^H < x \le L_{3,5}^H \\ t_{ACK}(L_{3,5}^H).\left\lfloor \frac{x}{L_{3,5}^H} \right\rfloor + t_{TX}(x \bmod L_5^M & x > L_{3,5}^H \end{cases}$$

The earlier definition incorporates the improvements in the modulation used (between 2 and 3 Mbps) that happen when the maximum payload of the different packet types is reached by the data. The variable $d_i(x)$ defines the time taken by the baseband for the transmission of x user data at rates of 1, 2, or 3 Mbps. This time can be determined from the number of symbols, $n_{symi}(x)$, to be sent in order to carry the data.

$$d_i(x) = t_{sym}.n_{symi}(x) + \Delta EDR_i \qquad \text{with} \quad i \in \{1,2,3\}$$

Where t_{sym} is a constant that determines the time for transmission of a symbol (1 μs, as 1 mega symbol per second is transmitted by BT. The extreme induced by using the improved rates of 2 and 3 Mbps for each of the rates employed is defined by ΔEDR_i). In particular, in order to allow the radio module to synchronize to the new modulation format, BT adds additional control and timing information under EDR.

This additional delay (ΔEDR_i) results from the total of three components, according to the BT specifications:

$$\Delta EDR_i = \begin{cases} 0 & i = 1 \\ t_{EDR_g} + t_{EDR_s} + t_{EDR_t} & (i = 2) \vee (i = 3) \end{cases}$$

- t_{EDR_g} is the time-guard between the last packet header symbol (encoded with GFSK) and the EDR Synchronization Sequence. This short duration allows the module of the BT radio to prepare for the shift in the modulation.
- t_{EDR_s} is the sequence with constant time of 11 μs required to transmit. The purpose of this sequence is to allow the synchronization of the timing and phase of the symbol for new modulation.
- t_{EDR_t} is the 2 μs corresponding to the unique 2 trailer symbol that must be inserted after the payload of the packet to mark the end of the packet? Based on standard requirements, the signal-to-noise ratio (SNR) can be determined from the demodulation algorithm considered. SNR is calculated for the Bit Error Rate (BER) given in equation 1. We still have an Intermediate Frequency (IF) of 2 MHz set for the baseband portion of the unit. Then, the internal noise of the receiver is calculated, as shown in equation 2, depending on the bandwidth considered:

$$BER \le 10^{-3}$$

$$N_s = 10\log(kTB) = -114\text{dBm}$$

A minimum input sensitivity is required by the BLE standard and a value of -80dBm is taken into account. The maximum noise figure of the unit can be calculated using the values obtained before and considering the Insertion Loss (IL) of -2dB.

$$NF = S_{in} + IL - N_s - SNR_{out,min}$$

$$NF = -80dBm - 2dB - (-114dBm) - 12dB = 20dB$$

The noise floor (n_{floor}) allows IIP_3 to be determined where P_{int} represents the power of in-band blockers.

$$n_{floor} = N_s + NF = -94dBm$$

$$IIP_3 = \frac{1}{2}(3P_{int} - n_{floor} - \Delta)$$

Zigbee Network Performance Metrics

Zigbee Application within scenario simulation times and is computed as:

$$T = \frac{Tps \times 8}{Tlps - Tfps}$$

The total packet sent, the time the last packet was sent, and the time the first packet was sent are denoted as Tps, $Tlps$, and $Tfps$ respectively.

$$AD = \frac{Tt}{Npr}$$

Where the average end-to-end delay, the total transmission delay of all received packets, and the number of packets received are denoted as AD, Tt, and Npr.

$$Tdp = Tpr - Tpt$$

Where the transmission delay of a packet occurs, the time packet received at the destination node and the time packet transmitted at the source node is referred to as the time packet received at the destination node Tdp, Tpr, and Tpt respectively.

RFID

The bit error probability (P_e) for noncoherent ASK demodulation is:

$$P_e = \frac{1}{2} e^{\frac{1}{2}\left(\frac{E_B}{E_0}\right)}$$

For a UHF backscatter device, the maximal achievable bit rate is:

$$R_{bit}(r, p_e) = P_s \Psi_T^2 \Psi_{ro} \times \left(\frac{\lambda}{4\pi r}\right)^4 \times M(r, R_o, N_B) \times \left(\frac{1}{k_B T_o f_r}\right) \times \frac{1}{2\ln\left(\frac{1}{2p_e}\right)}$$

The parameters k_B and T_o are the respective reference temperature and Boltzmann constants. The $M(r, R_o, N_B)$ signal attenuation factor accounts for non-line-of-sight conditions using a signal propagation model:

$$M(r, R_o, N_B) = \frac{1}{\left(1 + \frac{r}{R_0}\right)^{2(N_B - 2)}}$$

The parameters R_0 and N_B are the breakpoint distance equal to free space and the factors of environmental attenuation, respectively with $N_B = 2$ for free space, and the element becomes unity. A manufacturer of receivers usually defines the noise factor of the amplifier, as follows:

$$f_r = \frac{SNR_{in}}{SNR_{out}}$$

This is the same as the noise figure which is typically specified by dB value from equation 2.3 and equation (2) the Signal Noise Ratio can be written as :

$$SNR = \left(\frac{P_B M(r, R_o}{k_B T_0 f_r}\right) = R_{bit} \times 2\ln\left(\frac{1}{2pe}\right)$$

$$SNR_{min} = R_{bit} \times \frac{E_b}{N_0} \ |p_e$$

The highest tolerated probability of bit error (p_e) and the minimum SNR is required to decode a backscattered signal which is directly proportional to the bit rate. The higher SNR is needed if the application requires more range (r), lower bit error probability (p_e) or higher bit rate (R_{bit}) efficiency. Bandwidth is the difference in a continuous set of frequencies between upper and lower frequencies. It is normally calculated in hertz.

$$B = ((fH - fL)/FC)$$

The capacity of the channel is the tight upper limit of the rate at which data can be transmitted over a communication channel efficiently.

$$C = \log 2(1 + (S/N))$$

Oxygen, water vapor, fog, cloud and rain attenuation have a major impact on radio communication that operates in a millimeter frequency range. As a result, the power of the channel decreases. Compute the Signal to Interference Plus Noise Ratio between the transmitter and the receiver. Where the transmitter is denoted by i and the reviever is denoted by j.

$$SINR_{ij} = \frac{\frac{P_{T_x}}{PL_{ij}} G_{ij}}{\sum_{k \neq i} \frac{P_{Tx}}{PL_{kj}} G_{kj} + BW \times N_0}$$

Conclusion:

D2D communication is an exceptionally basic piece of IoT. Numerous industries and standardization bodies have shown extensive interest in the adoption of the D2D approach by wireless organizations. The D2D approach makes it easier to operate without the need for centralizing control to enhance the efficiency of wireless organizations with traffic offloading. Among networking devices, there is a wide range of IoT development applications. It is projected that this emerging technology will aid cellular networks in the next decade in reducing transmission time delays, conserving energy, and extending range. The Internet of Things (IoT) is introduced and referred to as a means of data exchange between D2D contact clusters that are simultaneously connected and fall under the jurisdiction of the cell organization. Architecture is provided with a brief overview of the D2D communication regarding its use cases. D2D organizing has already demonstrated its pivotal role in achieving the effective objectives of 5G wireless organizations. Initial systems that utilize D2D communication are just now beginning to emerge. To enhance IoT, more developments and industry standards are being established.

Recommendations:

- ✓ In order to create high-performance IoT applications, it is necessary to abide by the laws on data gravity.
- ✓ The frequency range should be underused without impacting the natural environment.
- ✓ With minimum deviations, location-based D2D resource allocation improvement is still needed.
- ✓ To reduce the transfer between base stations and also to enhance congestion management techniques, a new method is required.
- ✓ By using uplink and downlink radio networks, Fractional Frequency Reuse (FFR) with resource allocation under SC-FDMA can be further expanded. This can also be taken into account under Multicells by the use of link selection techniques.

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