5G Wireless Communications Systems: Heterogeneous Network Architecture and Design for Small Cells, D2D Communications (Low Range, Multi-hop) and Wearable Healthcare System on chip (ECG, EEG) for 5G Wireless

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Abstract

The major challenges in 5G wireless communication systems are the very high data rate, very low latency, very high mobility, very high density of users, very low energy cost and massive number of devices which cannot be addressed by the existing 4G-LTE, LTE-A. In this paper, heterogeneous networks architecture is proposed for the prospects of 5G wireless communications systems networks to address the future demand of the network capacity and seamless link for distributed radio access technology. The heterogeneous networks consist of the CRAN, small cells, cognitive radio networks, mobile femtocell, device to device (D2D) communications, low range D2D, mutihop D2D, M2M, massive MIMO and IoT which optimizes the industrial network growth, energy efficiency and higher QoS. The central and distributed backhaul is proposed for small cells. The D2D communication architecture is designed addressing the multi-hop D2D, D2D handover and low range D2D for wearable healthcare wireless chips. From the simulation results, it is found that the 5G backhaul energy efficiency and throughput increases with the increasing in number of small cells because of the adaptive spatial densification. The D2D energy efficiency is found decreasing with increasing number of small cell UEs surrounding and increasing D2D distance. In addition, the D2D SINR decreases with the increasing number of the wearable wireless healthcare system on chip and the D2D distance. Furthermore, the data rate in the multihop D2D is found decreasing with increasing mobility and increasing number of hops because of Doppler spread and multi-hop delay.

Keywords: *Device to Device Communication, Fifth Generation, Heterogeneous Network, Low Range, Multi hop, Small Cells, System on Chip, Wearable Healthcare*.

1. Introduction

The fifth generation (5G) heterogeneous architecture for wireless communications is proposed including the novel radio access and network technologies. According to mobile and wireless communications enablers for the twenty-twenty information Society (METIS), "the 5G requirements are 1-10 gbps/100s mbps data rate, capacity is 36TB/500GB per month per user, 10% of today's energy consumption, high frequencies and flexibility, 99% reliability, latency reduction to 1ms, more than 20 db of LTE coverage and 300,000 devices per access node for massive machines". To address METIS specification, the 5G wireless is proposed as the heterogeneous wireless networks to address the industrial demand for the next decade which can resolve the network capacity increment infinitely beyond macrocell capacity and provides seamless link for distributed radio access technology. The 5G heterogeneous network consists of the cloud regional area networks (CRAN), small cells, cognitive radio networks, mobile femtocell, low range D2D, mutihop D2D, M2M, massive multiple input multiple output (MIMO) and internet of things (IoT) as shown in Figure 1. This resolves the industrial network capacity growth, energy efficiency and seamless connectivity with high quality of service in heterogeneous environment. The spatial densification in 5G wireless can be done using either distributed implementation of small cells or macro cell along with small cells. The interconnection between macro cell with distributed small cells in heterogeneous network is better to implement so that different network access technologies can be deployed in small cells and macro cell connect to the backhaul networks CRAN [1].

The D2D communications provides the peer to peer data traffic between transmitting device and receiving devices directly with the good channel link, quality of service (QoS) and energy efficient connectivity without the role of base station. D2D communications improve reliability, latency, throughput per area, spectral efficiency and machine type access. D2D communications also provides extended coverage through muti-hopping, network coding, cooperative diversity. The prospective applications of D2D in 5G include the healthcare services, local services, commercial services, emergency communications and IOT augmentation. The specific D2D communications such as low range D2D and multihop D2D are also required to

formulate for 5G wireless systems. The low range D2D communications is necessary in 5G wireless communications for low range wearable wireless healthcare patches, wearable devices and smart mobile devices because of the limitations in the number of channels, nodes and data rates in Bluetooth, UWB, Wifi, Zigbee, and WPAN. Furthermore, multi hop D2D communications is deployed in 5G wireless, when there is not clear line of sight and signal is blocked by buildings, hills or mountains between small cell base stations. In such case, multi-hop D2D is established by D2D manager or small cell by searching the nearest neighboring D2D devices from neighboring buddy list and establishing the radio link between devices. Moreover, the mobility issue in D2D communications for 5G wireless is addressed considering low latency, high signal to interference noise ratio (SINR) and low signaling overhead during D2D communications. The D2D control is handover from one small cell or macro cell to another small cell or macro cell whenever the D2D-SINR in existing cell is below the threshold SINR such as 1bps/Hz/mw specified as the minimum requirement to maintain the D2D control.

In the 5G era, there is the shift towards network efficiency with 5G systems based on dense heterogeneous network architectures. The evolution of the heterogeneous architecture includes small cells, CRAN, D2D communications and virtual radio access technology. 5G heterogeneous wireless architectures have potential cellular architecture to separate indoor and outdoor scenarios and implements promising technologies, such as massive MIMO, energy-efficient communications, cognitive radio networks, and visible light communications. The key technology in 5G wireless include cognitive radio networks, mobile femotcell, small cell, green communications, visible light communications [2]. However, D2D communications is also major in 5G wireless systems for both indoor and outdoor which is not addressed. Regarding the backhaul for 5G wireless architectures, the central and distributed solutions for small cells along with macro cell can be implemented [3]. The central and distributed backhaul system can be implemented in heterogeneous architecture where small cells are equipped with different radio access technology such as D2D, massive MIMO, millimeters waves, mobile femtocell, CRNs, vehicle to vehicle (V2V) along with CRANs etc. D2D has location discovery and direct communications between proximate devices that improves communication link and QoS. D2D is documented by 4G-LTE-A standard in 3rd generation partnership project (3GPP) Release 12 [4]. However, D2D communications need to be addressed in 5G wireless networks over distributed small cells implementation along with CRANs which is addressed in this paper. Moreover, D2D has some

challenges about security, interference management, resource allocation, and service pricing in commercial activities [5]. These are better taken care by joint cooperation of D2D manager, small cell or macro cell base station and CRAN backhaul in 5G wireless systems. On the other hand, D2D aware handover and D2D triggered handover for D2D mobility solutions can reduce the network signaling overhead and improve the D2D E2E latency by maximizing the time period when the DUEs are under the control of the same small cell [6]. However, D2D handover can be conducted better considering threshold SINR as well as density of nodes in the small cell by joint cooperation of D2D manager and small cell base station.

The next generation wearable devices in 5G wireless networks are wrist held health monitoring device and smart sousveillance hat beyond wearable watch, glass, band and clothes. The smart health monitoring device collects and observes different health related information deploying wearable wireless Soc patches or biosensors and can predict health problems by analyzing the physiological information collected via different patches or biosensors [7]. The advance wearable devices have D2D communications capability in LTE assisted networks via D2D server, D2D application server, and D2D enhanced LTE signaling, using in-band and out-band spectrum. Moreover, the wearable devices are smart mobile device for D2D communications in small cells and macro cells using 5G wireless backhaul networks which is addressed in this paper. The D2D communications performance can be significantly improved in 5G as compared to LTE assisted networks because millimeter wave technology is used for higher data rate and co-channel interference mitigation and distributed CRAN in backhaul.

2. Problem & Proposed Solution

The problem statement of this paper is to study and analyze the challenges in 5G wireless communications system and prospects the heterogeneous architecture for 5G wireless systems which can address the growing industrial network capacity, spectrum efficiency, energy efficiency, Qos and seamless link for distributed radio access technology. The heterogeneous architecture is capable for better coordination of macro cell, small cells, CRNs, massive MIMO, D2D communications, M2M, V2V, IoT with CRAN. The second objective of this research is the architectural design, protocol development and performance analysis for D2D communications, D2D handover, multi hop D2D and low range D2D for wearable healthcare applications in 5G wireless. On the other hand, this paper also focus on low powered system

on chip design for wearable healthcare chips design so that real-time voltage and frequency amplification, analog to digital processing, clock optimization, network on chip, state machine, microprocessor or microcontroller and reliable low range D2D wireless communications can be done in 5G wireless networks. The basic design constraint for wearable healthcare systems on chip are noninvasive, wireless power transmission or renewable energy from body temperature and sub-10nm designs. The contribution of this paper is that it has illustrated the heterogeneous architecture for 5G wireless systems, different modes of D2D communications in small cells, and wearable biomedical Soc design.

The proposed solution includes the following aspects:
- Specifying and designing 5G heterogeneous architecture including small cells, CRN, Femto cell, pico cell, D2D, massive MIMO
- Small cells design and modeling for 5G wireless backhaul networks with distributed system and central system
- Designing the low range D2D communications for wearable Soc patches and devices
- Designing D2D handover protocol and multi-hop based D2D communications protocol for 5G wireless
- Designing wearable wireless healthcare Soc architectures ECG and EEG for low range D2D communications
- Simulation of 5G throughput, energy efficiency, SINR, D2D handover and datarate

2.1 Heterogeneous Architecture

5G wireless systems focus on the network capacity efficiency, Qos, spectrum efficiency and seamless networks connectivity between different radio access technologies whereas 3G and 4G concentrate peak data rate and spectrum sharing. The implementation of 5G wireless can be achieved only via heterogeneous networks architecture as shown in figure-1. The heterogeneous networks consist of macro cell in licensed bands, distributed small cells for spectrum spatial sharing in licensed and unlicensed bands. The small cells are equipped with different radio access technologies such as D2D communications, cognitive radio networks, mobile femtocell, high frequency millimeters waves for ultra density networks, massive MIMO, virtual core networks, wifi and IoT in heterogeneous platform as shown in figure-1. The front-haul small cells with different radio access technologies are connected to backhaul WRAN and mobile core either through central macro cell or distributed CRANs of small cells to provide seamless connectivity. It also co-operates the network densification,

mutli cell cooperation, multi radio access internetworking, cloud architecture and virtual networks. According to shannon's capacity theory, the total system capacity C_{sum} of 5G wireless cellular systems can be represented as follows:

$$C_{sum} = \sum\nolimits_{HET\text{-}NETs} \sum\nolimits_{channels} [B_n * Log_2(1 + P_n/N_P)] \qquad (1)$$

where, P_n is the signal power of the nth channel, N_P is the interference noise power and B_n is the bandwidth of the nth channel.

The total system capacity is the sum capacity of all sub-channels deployed in heterogeneous networks. The total system capacity can be increased by increasing network coverage through heterogeneous networks implementation of macro cell, small cells, mobile femtocells, D2D clustering and increasing the number of sub-channels via D2D communications, cognitive radio networks, massive MIMO, millimeters waves, visible light communications. Cloud or Centralized Regional Area Networks (CRAN) centralizes various radio resources to manage and dynamically allocate on demand using the coordination of multiple antenna ports or cells and joint processing of radio signals. CRAN consists of a number of transceiver points connected to common base band processing unit and connection of transceiver points to processing mostly using optical fiber. The virtual transmit nodes can be deployed to avoid fixed cell concept and cells can be virtually introduce as dynamic cell for WRAN. Centralized CRAN covers the huge area whereas the local CRAN covers a small area such as hot spot area in city. CRANs are connected together via internet, aggregation networks or mobile core with centralize or distributed functions. The merits of CRAN are sustain multi radio access technology (RAT) with virtualizations, massive cooperation of multiple antennas, efficient solution of intra and inter cell interference, optimized radio resources in time/frequency and resource domain, core related functions and virtualized platforms. The major challenges for CRAN in 5G wireless are control of heterogeneous implementation using software defined networks, network traffic control and Qos management, integration of fronthaul and backhaul, interference and mobility, cooperation and interaction among private and operator owned CRANs, and cloud edge design.

Massive MIMO has capability of configuring the ten thousands of arrays at the base station which can exactly control beam and provide the higher spectral performance than legacy MIMO of less than eight antenna arrays. The massive MIMO includes the spatial multiplexing for spectral efficiency, energy efficiency and interference mitigation for optimizing system capacity addressing

channel assignment, antenna arrays, code book design and SNR. It can be implemented as the coordinated multi-point transmission (CoMP) which is distributed massive MIMO and centralized massive MIMO is the extension of CoMP. In massive MIMO implementation, the transmitter and receiver are equipped with a large number of antennas elements may be tens or more transmitter antenna can be co-located or distributed in different applications for spectral efficiency.
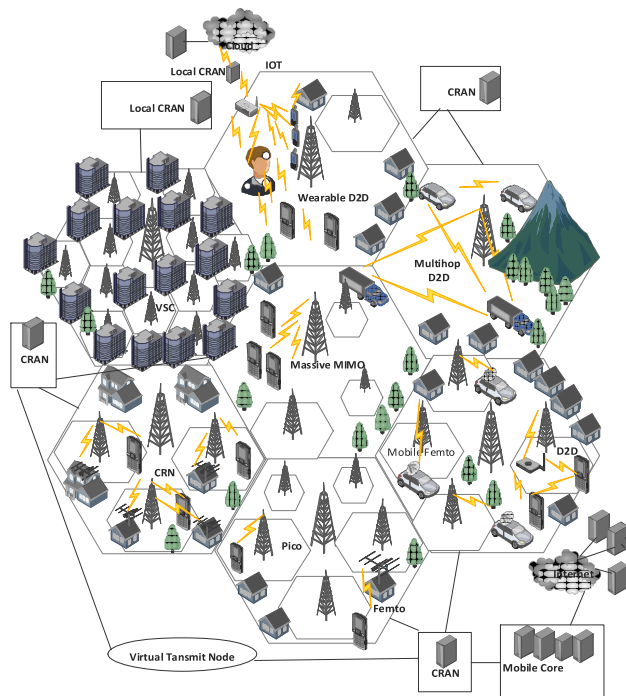

Fig. 1 Heterogeneous architecture in 5G wireless system

Mobile femtocell is different as compared to traditional home based femtocell in terms of mobility and spectral utilization. The mobile femtocell network is the fusion of relay in the femto cell implementation which can dynamically change the network connectivity to the service provider core networks. It has capability to significantly increase the spectral performance by using both orthogonal and non-orthogonal resource allocation. In addition, it can optimize the SNR, spectral utilization with base station (BS), overhead reduction, energy saving for end user and proper handover in highly mobile environment. The optimization of cellular resource can be done using mobile femto cells similarly like femto cell, by deploying smart antennas applications and effective power adaptation method which significantly optimize the cellular coverage, channel capacity, power usage, and intra and inter tier interference [8].

Cognitive Radio Networks (CRN) is the novel software defined radio technique which reuses the available

licensed spectrum holes for secondary users in the absence of primary user. The primary users are the licensed users for licensed spectrum whereas secondary users are unlicensed users. In cognitive radio networks, secondary users or cognitive radio users can borrow the spectrum resources without making interference, when the primary users are not using them. This is addressed by secured distributed MAC and complexity reduction in channel estimation for cross-layer based cognitive radio networks, which provides outstanding performance for robustness, symbol error rate, joint power control and link scheduling [9]. The interference tolerance networks with interference state monitoring for licensed users from the spectrum control can be done before allocating cognitive users. The multiple cognitive networks can be implemented in one macro cell along with small cells using hybrid networks.

Fig. 2 Small Cells in 5G wireless system

2.2 Small Cell

The adaptive spatial densification is extensively required in 5G for both urban and suburban homes, enterprises, offices and business complexes which resolve the site acquisition, rental and back haul cost of pico-cell implementation. This is addressed by extensive implementation of small cells which does not require detail RF planning, site acquisition and can be installed more conveniently and connected to distributed CRAN as shown in figure-2. Small cell support self organizing networks and low cost portable networks development as compared to macro-cell and pico-cell. D2D can also be implemented with small cells for D2D enabled devices in the neighborhood and IoT for wearable health monitoring sensor patches and smart sensor grids. Specifically, the coverage of small cells is 25 to 125 meters or more in radius and be deployed up to 50 small cells in a macrocell. The importance of small cells is that it can provide the significantly huge amount of data capacity and network traffic as compared to macro when using the seamless mobility throughout macro-small cell network or small - small cell network. The self organizing network features such as self configuration, mobility management and backhaul load balancing enable small cells for spatial network densification via removing RF planning as well as straight plug and play by end devices. Moreover, the small cells support IOT communications in its vicinity to upload data into the cloud, for smart sensor grids including health

monitoring sensors, surveillance and security sensors, home appliance and utility sensors, nearby vehicle sensors etc. In addition, the small cells also support D2D and multi-hop D2D for D2D enable devices in both in-band and out-band modes.

The small cells are implemented within a macro cell or eNB either as central system or distributed system as shown in figure-3. In central system, the wireless backhaul network traffic of small cells base stations are forwarded to macro cell base station or eNB using millimeter wave communications and aggregate backhaul traffic at macro cell is forwarded to CRAN or mobile core via fiber to the cell. In the distributed system, there is not macro cell base station or evolved nodeB (eNB) and all the backhaul traffic from small cells base stations is relayed to specific small cell base station using millimeter waves and forwarded to CRAN or mobile core by fiber to the cell.

The backhaul traffic model for vicinity small cells implementation with macro cell or eNB in central system is represented by computing the total system throughput [3]. The uplink throughput of small cell is computed as 0.05 times product of the bandwidth of small cell and the average spectrum efficiency of small cell. The downlink throughput of small cell is 1.15 times of product of the bandwidth of small cell and the average spectrum efficiency of small cell. Similarly, the uplink throughput of macro cell is 0.06 times the product of the bandwidth of mcaro cell and average spectrum efficiency of macro cell. The downlink throughput of macro cell is 1.16 times the product of the bandwidth of macro cell and average spectrum efficiency of macro cell. The total throughput in for central system is the sum of the throughput in uplink and downlink of macro cell and the total throughput in uplink and downlink of nth number of small.
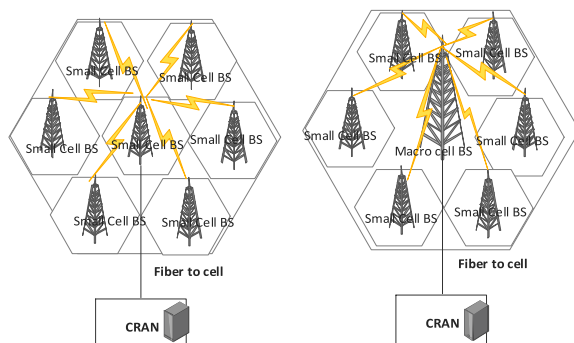

Fig. 3 5G Wireless Backhaul Networks for Distributed system and Central System

The base station operating energy depends upon the product of base station operating power, wearing factor and the lifetime signal power, range and channel fading.

The embodied energy of base station is the initial energy and the maintenance energy. The system energy consumption depends upon the sum of operational energy and embodied energy in both macro cell and small cells. The energy efficiency in the central system is the ratio of the total throughput in the central system and the system energy consumed.

Furthermore, the total throughput for distributed system is the sum of throughput for n^{th} number of small cells in both the uplink and downlink. The uplink backhaul throughput of cooperative small cells is 1.15 times the bandwidth of small cell and spectrum efficiency. The downlink backhaul of throughput for cooperative small cell is 1.15 times the bandwidth of small cell and cooperative spectrum efficiency. The system energy consumption is the sum of operational energy and embodied energy for n^{th} number of small cells in a cooperative cluster. The energy efficiency in the distributed system is the ratio of the total throughput in the distributed system and the system energy.

2. Device to Device (D2D) Communications

The cellular based D2D communications is known as proximity service in which the payload data is directly transmitted between the end devices and routed through eNBs and core networks. D2D communication is essential in 5G as it can provide low power, high data rate, low latency services which significantly increase the spectral efficiency, user experience, health care and communication applications. It allows reuse of resources between D2D users, D2D networks, cellular networks for reuse gain and hop gain resulting to the increase in spectral efficiency and throughput. In addition, the rising mobile services and technologies focusing on the short distance data sharing for nearby users boost up the user experience via D2D communications. The D2D services include the health care monitoring, location services, social and commercial activities. The D2D communications also allow communications between end users via multi-hop D2D even though the core network is damaged or out of service. The D2D need to address the unicast communication, D2D clustering, multi-hop link on obstacles and other functions in 5G, for potential network capacity gain which is not addressed in 3GPP LTE Release 12.

The potential applications of 5G D2D include the healthcare services, local services, emergency communications and IOT augmentation. The low range D2D based healthcare service includes the implementation of wearable wireless patches, wearable medical devices and smart mobile devices as shown in figure 4. The

physiological information such as ECG pulses, heart rate, blood pressure, blood oxygen, glucose, drug or alcohol content, physical stress and EEG brainwaves determined by wearable wireless Soc patches and monitored by smart phones using low range D2D communications and forwarded to other mobile devices or doctors as shown in figure-4. The fusion of wearable patches or devices and D2D provides the wearer to monitor the health information independently for 24X 7 without going to any medical center. The collected physiological health information can also be uploaded to medical cloud via internet of wearable medical sensor patches.

The D2D based local services are provided using social apps depending on the proximity feature using D2D discovery and communication functions for data sharing among nearby users. The feature application of D2D communications is emergency communications during the natural disaster when the cellular infrastructure is damaged. The D2D wireless connection between D2D enabled devices can set up single hop or multi-hop communications. The multi hop D2D can be configured when there is not clear line of sight between mobile devices due to obstructions such as buildings, hills etc. Moreover, the important application of D2D communications is IoT which consists of several hundred or more wireless sensors connected into extensive networks together as shown in figure-4.
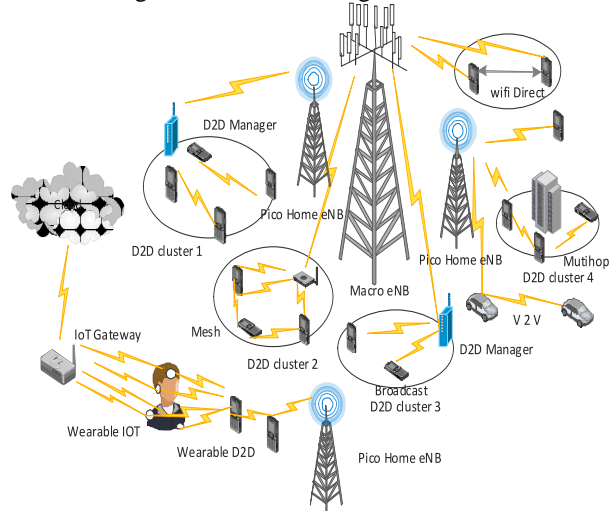

Fig. 4 D2D, Low range D2D for wearable SoC, and IOT in 5G wireless system

The D2D discovery in vicinity is implemented using proximity discovery, networks discovery, node/peer discovery, priori discovery and posteriori discovery. The D2D communications under licensed or inband spectrum use the cellular spectrum for both the cellular link and D2D which provides high control over cellular spectrum. In underlay inband D2D, cellular and D2D communication

share the same radio resources whereas in overlay inband D2D, cellular and D2D are assigned to dedicated cellular resources. Underlay D2D provides higher spectral efficiency in D2D communication than overlay D2D and the cellular spectrum can be completely managed by the eNB whereas resources might be wasted in overlay. On the other hand, the D2D communications under unlicensed or outband spectrum use unlicensed spectrum in D2D communications to reduce the interference between D2D and cellular links which requires an extra interface such as Wi-Fi direct, ZigBee or Bluetooth. There is no interference with cellular communication or unlicensed spectrum in outband D2D, which enables users to have simultaneous cellular and D2D transmission. However, the transmission distance and data transfer rate is tremendously lower than inband D2D communication.

3.1 Low Range D2D Communications for Wearable Soc patches and Devices

The low range D2D communications is necessary in 5G wireless for D2D communications between the wearable wireless healthcare patches, wearable devices and smart mobile devices. There is limitation in the number of channels and nodes in bluetooth and ultra wideband (UWB). Similarly, Wifi, Zigbee, and wireless personal area networks (WPAN) protocol have limited data rate and number of channels. These existing low range communication protocols cannot provide the higher data rate, higher nodes connectivity, low powered higher capacity data transmission and lower latency which is the basic feature of 5G wireless and therefore the low range D2D protocol for wearable healthcare patches or devices is proposed. The range can be from few meters to 10 meters for low range D2D communications using millimeter wave or ISM band. The wearable wireless healthcare patches include different health information monitoring SoC patches and implant sensors which can wirelessly communicate with smart devices or mobile devices using low range D2D communications. This paper includes detail healthcare SoC architecture design about EEG and ECG system on chip patch. The wearable devices include smart watch, smart hat, smart glass, virtual reality device and other wearable health tracking devices. The low range D2D protocol is illustrated in figure-5.

The wearable sensor patches are capable for wireless communication in less than 1m to 10m. Once the physiological information is instantly measured from wearable SoC patch then it broadcasts D2D connection request to smart devices. If any smart or mobile device receive the D2D request from patch then it immediately respond with D2D connection configured. Then, patch will instantly send the physiological information measured

such as ECG pulses and EEG brainwaves depending upon the nature of measuring sensor electrodes or sensor array attached with the patch. The smart device can collect different physiological information instantly from different wearable wireless patches simultaneously implementing millimeters waves or MIMO antenna on the smart mobile device. Moreover, the smart mobile device can forward the received physiological information to another mobile device by establishing D2D connection simultaneously with patch and another mobile device, and forwarding the received data to another mobile device once received from patch. Thus, the low range D2D communications for wearable patches or devices can be extended by forwarding or multihop connection between or among smart mobile devices.
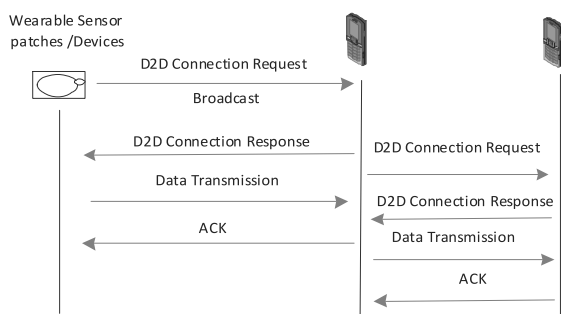
Fig. 5 Low range D2D protocol for Wearable wireless healthcare patches to Smart devices

On the other hand, wearable wireless health monitoring patches can also form the IoT consisting healthcare patches, implant sensors, tags, badges and wearable devices and upload the measured and collected information to cloud through the IoT gateway. Hence, healthcare patches and sensors provide the physiological information whereas tags and badges provide the identification, location, and tracking activities of wearer. IoT basically generates big massive data in the distributed data storage which can be accessed by any smart or mobile devices using Internet or Intranet. Thus, IoT is deployed instead of D2D in 5G wireless when there is significant amount of sensors generating huge amount of data spontaneously. IoT also supports M2M communications between several independent machines connected through internet.

3.2 D2D Communications Protocol

The proposed D2D communications in 5G is illustrated in Fig 7. The requesting mobile eUE1 first sends radio resource connection (RRC) request to D2D manager in its D2D cluster which is forwarded by D2D manager to Pico-eNB or small-cell-eNB or eNB for RRC authentication,

integrity and control. The eNB or Pico-eNB has backhaul connection to MME and SGW/PGW in CRAN. MME keep the updated location information, tracking information and list of neighboring buddy which is used for D2D nodes discovery. MME also authenticate eUEs, device handover, selection for PGW and SGW. In addition, SGW authenticates subscriber account, defines QoS and provides access to heterogeneous services such as D2D services, massive MIMO services, cognitive radio services, mobile femto services, pico-cell and vicinity small cell services in 5G wireless system. PGW provides the eUE IP address allocation, packet filtering, network connectivity. Once the D2D manager received response on RRC authentication, integrity and control from pico-eNB or eNB then it sends the response with RRC connection configured to requesting mobile eUE1. Hence, D2D manager receive the specific in-band channels for D2D communications from pico-eNB or eNB. Then, eUE1 requests D2D manager for uplink shared channel to connect eUE2. The D2D manager activate scanning the channels and assign the unused channel for D2D uplink shared channel for both D2D mobile devices eUE1 and eUE2 as shown in figure-6.

In some cases, there might not be clear line of sight and signal might be blocked by buildings, hills or mountains between eUE1 and eUE2. Under these scenario, multi-hop D2D need to be established which can be done either by D2D manager or pico-eNB by searching the nearest neighbor eUE3 from neighboring buddy list and establishing the radio link to eUE2 through eUE3. Once the shared uplink is established either direct or multihop, the transmitting eUE1 send data transmission using the assigned uplink channel to eUE2 and through eUE3 if it is intermediate node between eUE1 and eUE2. The receiving eUE2 respond with Ack/Nack message to D2D manager and transmitting eUE1 as shown in figure-7. Ack means the data received successfully and Nack means not received and need to retransmit again. Thus, the D2D communications is done between transmitter and receiver pair, with or without an intermediate node.

3.3 Handover in D2D Communications

The mobility issue in D2D communications for 5G wireless is addressed considering lower latency, higher signal to interference noise ratio and lower signaling overhead of multiple radio resource control during D2D communications. The D2D control is handover from eNB1/Pico eNB1/small-cell eNB1 to eNB2/Pico eNB2/small-cell eNB2 for D2D pair eUE1 and eUE2 is done whenever the D2D-SINR in eNB1/Pico eNB1/small-cell eNB1 is below the threshold SINR such as 1bps/Hz/mw specified as the minimum requirement to

maintain the D2D control as shown in figure-8. In addition, the density of eUEs in eNB/pico cell/small cell should be significantly higher so that node discovery and D2D handover can be done based on D2D buddy list with lower control overhead and extend multihop D2D control.
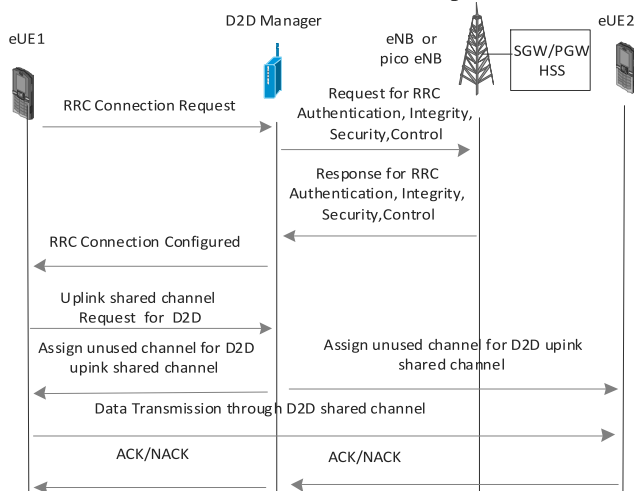

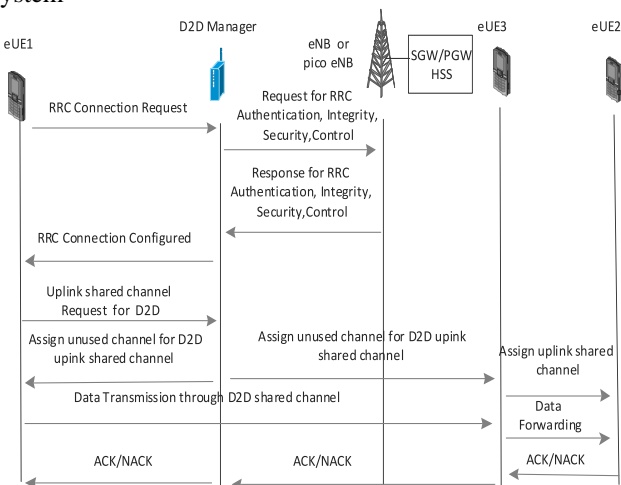Fig. 6 D2D communications protocol for 5G wireless system

Fig. 7 Multi-hop based D2D communications protocol for 5G wireless

When the D2D-SINR in eNB2/Pico eNB2/small-cell eNB2 is comparatively higher than other eNBs and above the threshold SINR specified as the minimum requirement to maintain the D2D control and higher presence of eUEs in D2D buddy list, then D2D control handover is done to eNB2/Pico eNB2/small-cell eNB2 from eNB1/Pico eNB1/small-cell eNB1. As long as, the D2D pair between eUE1 and eUE2 is connected, the D2D pair control is handover among different eNBs/Pico eNBs depending upon their mobility and D2D range. Similarly, multihop based D2D can be configured and handover multihop D2D control between the eNBs based on SINR and node

density. This has extensive application in V2V communications where there is lower overhead signalling and SINR threshold is pragmatic requirement.

The D2D communication has D2D manager which authenticate, establish uplink for D2D communications cooperating with eNB/pico eNB/small-cell eNB, execute D2D control and inform eNB for D2D handover. The D2D manager M1 detect the D2D pair location, SINR over channel assigned by eNB1/Pico eNB1 for D2D communications in eNB1/Pico eNB1 and if it is found below threshold SINR then, it is time to handover to another eNBs as shown in figure-8.a. However, the eNB1/Pico eNB1 will not handover D2D control and handover is pending for UE1 and UE2 to eNB2/Pico eNB2 until the SINR is above threshold and significant node density found in eNB2/Pico eNB2 as shown in figure -8.b. When the SINR above threshold SINR and significant node density is found then D2D handover is executed from eNB1/Pico eNB1 to eNB2/Pico eNB2 and D2D manager M2 take control over D2D communications as shown in figure-8.c. In V2V, communications there is no requirement for D2D manager because eNB/Pico eNB itself operate as D2D manager to reduce the handover signaling overhead.
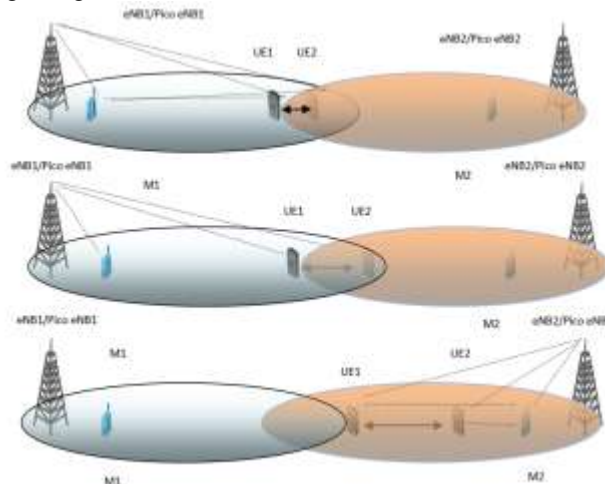

Fig. 8 (a) UE1 and UE2 under the control of D2D Manger M1 and eNB1/Pico eNB1, (b) D2D handover is pended by eNB1/Pico eNB1, (c) D2D handover is executed from eNB1/Pico eNB1 to eNB2/Pico eNB2.

4. Wearable Wireless Healthcare SoC Architecture Design for Low Range D2D Communications

The basic requirements of wearable device are good aesthetics, water tolerance, miniature size, lower power consumption, wireless connectivity, real-time operating system, Apps processor or microcontroller. The healthcare

related wearable wireless devices need to be very small in size so that different physiological information can be instantly determined, tracked and collected in smart device or uploaded to medical cloud through gateway to Internet of Things. In this paper, wearable wireless patches are designed in the form of system of chip so that these patches can be conveniently worn and massive physiological information from these patches can be collected and monitored by smart device or mobile device simultaneously using low range D2D communications in 5G wireless as shown in figure-5. Several patches can simultaneously communicate to a smart device or mobile device, which enable wearer to track the heath information without going to any medical lab, hospital or even using any handheld or portable medical devices. In this paper, the proposed wearable Soc architectures are for ECG measuring patch and EEG measuring patch. These wireless smart patches are non invasive, comfortable to wear and have low range D2D communications capability to store instant data in smart device, mobile device and cloud. The design issue for wearable SoC is the power supply which is addressed by wireless power transmission or rechargeable battery from body temperature.

4.1 Wearable Electrocardiograph (ECG) SoC Architecture

The wearable ECG SoC can detect and measure ECG pulses as well as low range D2D wireless communication to the smart device and access internet of things. The proposed wearable ECG sensor is a SoC with 2mm X 1.2 mm in dimension. It consists of a finite state machine (FSM) as controller instead of microprocessor or microcontroller because FSM is preferred to reduce fabrication cost, power consumption and miniature size for 5G wireless. The major components of ECG SoC are the fabric inductor, attenuated total internal reflection (ATR) modulator, low dropout (LDO), nested chopping amplifier (NCA), programmable gain amplifier (PGA), instrumentation amplifier (IA), analog to digital converter (ADC) as shown in figure-9.
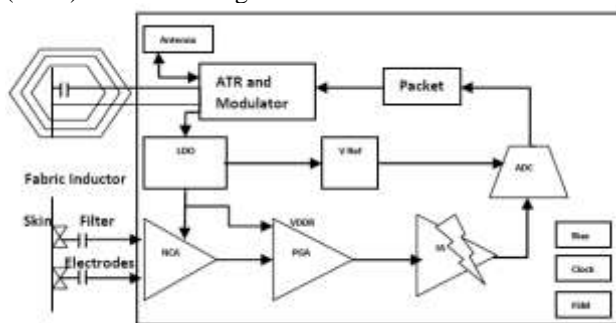

Fig. 9 Wearable ECG SoC Architecture

4.2 Wearable Electroencephalography (EEG) SoC Architecture

The noninvasive EEG is the main modality to study and analyze the brain dynamics and performance in real-life interaction of humans and portable wireless wearable EEG solutions require improvements when processing electrical signals of the brain. This is addressed by sensory inputs, brain signal generation and acquisition, brain signal analysis, and feedback generation [10]. However, wearable wireless Soc architecture for EEG signal monitoring can only make it possible to deploy in 5G wireless networks. The wearable EEG SoC can detect and measure EEG brainwaves and low range D2D wireless communication to the smart device and access internet of things. The proposed wearable EEG Soc with FSM as controller is 2 mm X 1.5 mm in dimension for miniature chip size, lower power consumption and fabrication cost as shown in figure 10. The major components are the EEG electrodes, fabric inductor, ATR modulator, instrumentation amplifier (IA), operational amplifier (OA), notch filter, right leg driver, pass band filter, protection circuit and ADC as shown in figure-10.
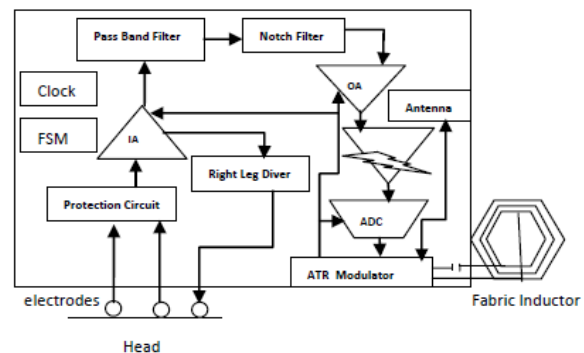

Fig. 10 Wearable EEG SoC Architecture with FSM as controller

5. Simulation Results

The 5G wireless backhaul along with small cells and D2D implementation is simulated and analyzed using different simulation parameters in the simulation platform. The size of macro cell is about 1300 meters and vicinity small cell is 25 to 125 meters in radius generated randomly. The number of small cells is about 10 to 50 generated randomly, number of CRN is 1 to15 randomly, path loss coefficient (alpha) is 3 to 5. The range for low range D2D using wearable wireless patches for health monitoring (EEG and ECG sensing) is 10 meters whereas the maximum D2D range is 300 meters. The maximum number of wireless patches that one smart or mobile device can communicate simultaneously is 15. The

maximum number of D2D devices in one small cell is 120 and the maximum D2D range is 300 meters. The SINR for D2D handover is above 1bps/hz/mw. The number of hops for D2D is up to 5 and D2D relative mobility is up to 50m/s. The life time for macro cell eNB and small cell are 10 and 5 years respectively.

The backhaul energy efficiency or throughput increases with the increase in number of small cells in both the central and distributed system because of the adaptive spatial densification. In central system, the network traffics are transmitted to macro cell base station from all macro cells whereas network traffics are transmitted to one small cell before forwarding to CRAN in distributed system. The backhaul throughput performance in distributed system can increase more than central system because of the cooperative spectral efficiency. In simulation, increasing the number of small cells with uniform 25m in radius up to 50 cells, the energy efficiency is found 143mbps/GJ and 50 mbps/GJ with spectral efficiency of 30 b/Hz and 5 b/Hz in the central system, shown in figure-11.
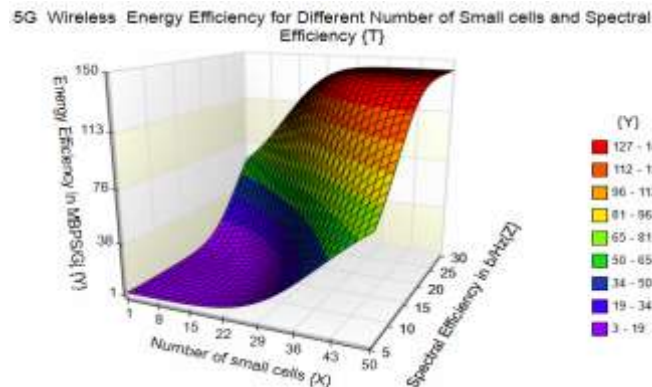

Fig. 11 Backhaul Energy Efficiency in Small cells

As the path loss coefficient increases, the attenuation effect of the wireless capacity increases which reduce the 5G wireless backhaul energy efficiency in distributed system as shown in figure-12. The reduction of energy efficiency is significantly higher in central system than distributed system because of there is relay among small cells in distributed system to CRN whereas there is direct communications from small cell to macro cell directly and relay in central system. The significant impact of attenuation is observed after increasing the size of small cell whenever more than 55 meters. The energy efficiency of 345 Mbps/GJ to 63 Mbps/GJ found at path loss coefficient 3 to 5 and radius of small cell 25 to 125 meters.
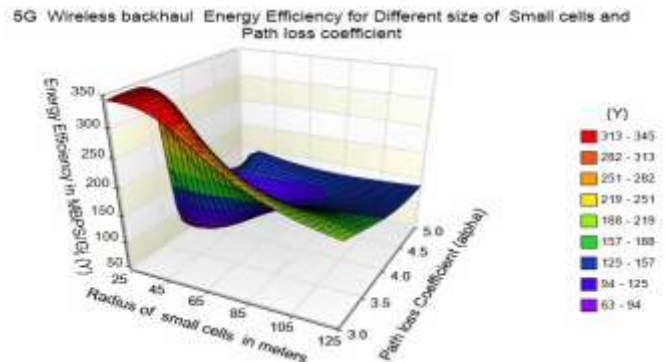

Fig. 12 Wireless Backhaul Energy Efficiency with the size of small cells and pathloss

The energy efficiency increases with the increasing number of small cells and cognitive radio networks because of the spectrum reuse of the unused spectrum holes by small cell users as secondary users. Since cognitive radio networks use high bandwidth, small users and macro cell users can use the spectrum holes and optimizing the spectrum efficiency and backhaul efficiency. In central backhaul system, the energy efficiency is found increasing after CRNs more than 7 and optimizing density of small cells. The energy efficiency is found 438 Mbps/GJ and 65Mbps/GJ at number of CRNs 15 and 1 while optimizing the number of small cells as shown in figure-13.
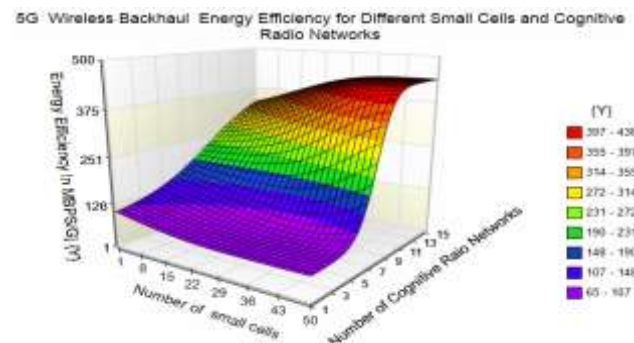

Fig. 13   Wireless Backhaul Energy Efficiency using Small cells and CRN

The D2D energy efficiency is found decreasing with increasing number of small cell UEs surrounding and increasing D2D distance. From simulation, it is found that the energy efficiency of 90 Bps/Hz/mw. In worst case, the energy efficiency of 11 Bps/Hz/mw when surrounded small cell UEs of 15 found in D2D distance of 300m as shown in figure-14. The major reason in reduction of D2D energy efficiency is the higher interference from small cell users in their strong population surrounding D2D users.
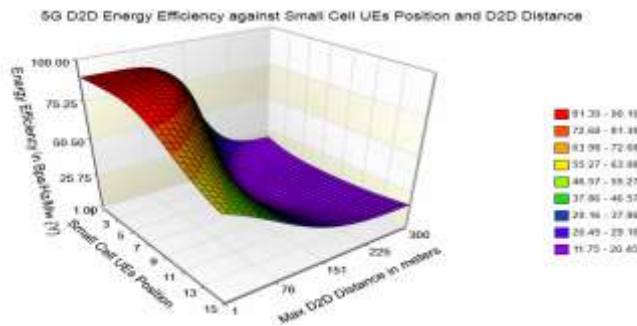
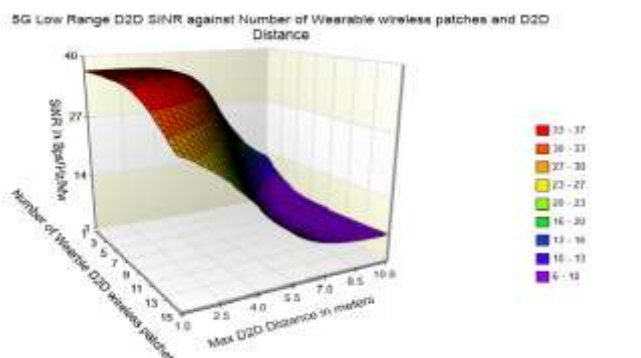Fig. 14 D2D Energy Efficiency with small cell UEs and D2D distances

Fig. 15 Low Range D2D SINR for Number of wearable wireless health monitoring patches

The low range D2D communications in 5G wireless allow several wireless patches to communicate with one smart or mobile device simultaneously. The simulation shows that the D2D SINR decreases with the increasing number of the wearable wireless patches used for instantly monitoring health information and increasing D2D distance as shown in figure-15. The The reduction in D2D SINR is because of the severe cross interference from multiple patches at the receiving device and low power signal transmitted from wearable patches which is faded with increasing the D2D distance. The D2D SINR is found 37 Bps/Hz/mw to 6 Bps/Hz/mw at number of wearable patches from1 to 15 and D2D distance 1 m to 10 m as shown in figure -15.
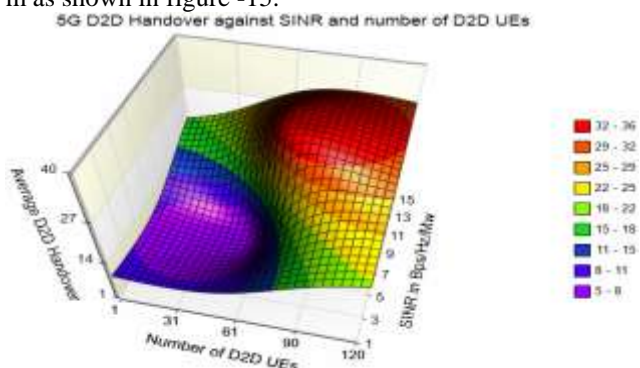

Fig. 16 D2D Handover against D2D UEs and SINR

The D2D handover is executed whenever the SINR in the existing macro cell, small cell or pico cell is below the threshold SINR of 1 Bps/Hz/mw. At this moment existing eNB/Pico eNB2/small-cell eNB handover D2D communications to another eNB/Pico eNB/small-cell eNB based upon the SINR and density of nodes. The average D2D handover is found significantly increasing when the density of D2D UEs nodes is above 60 and SINR above 7 Bps/Hz/mw found in neighboring cell for specific period as shown in figure-16. When the D2D nodes are highly mobile and found another small cell providing more than threshold SINR and high density, the D2D handover is significantly increased to provide better SINR and QoS to D2D communications.
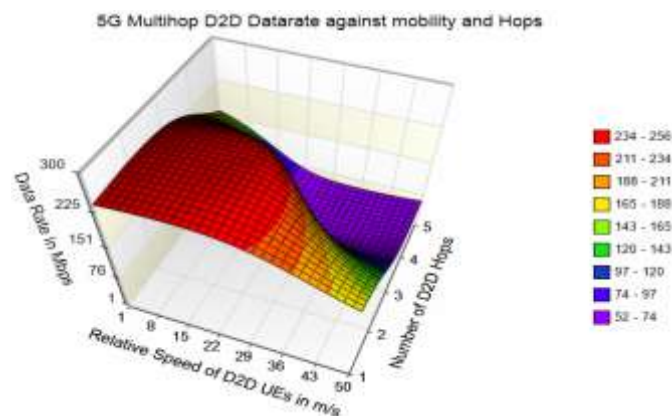

Fig. 17 D2D Multi-hop data rate against mobility and hops

The multi-hop D2D communications is very essential in 5G wireless systems, whenever D2D devices cannot directly establish the D2D link to communicate because of the obstruction such as building, mountain, hill in between D2D devices. The multi-hop link connectivity is established using the mobile ad-hoc networks based DSR routing under the control of the D2D manager or small cell eNB/pico cell eNB. The data rate in multihop D2D decreases with increasing mobility and increasing number of hops because of Doppler spread and multi-hop delay [11]. The D2D data rate is found 256 Mbps to 52 Mbps at relative speed of 1 m/s to 50m/s at number of hops from 1 to 5 as shown in figure-17.

6. Conclusion

The 5G heterogeneous network consists of the CRAN, small cells, cognitive radio networks, mobile femtocell, low range D2D, mutihop D2D, M2M, massive MIMO and IoT which optimizes the industrial network growth, energy efficiency and high quality of service in heterogeneous environment. The spatial densification in 5G wireless is achieved by distributed implementation of several small

cells and CRNs inside macro cell and allowing D2D communications between mobile devices. The low range D2D communication protocol for wearable healthcare SoC patches, D2D communication protocol, multihop D2D protocol and D2D handover are developed in this paper. From the simulation results, the 5G backhaul energy efficiency and throughput increases with the increasing in number of small cells in both the central and distributed system because of the adaptive spatial densification . The raising path loss coefficient causes to the attenuation effect of the wireless capacity which reduce the 5G wireless backhaul energy efficiency in both central system and distributed system. The 5G backhaul energy efficiency increases with the increasing number of small cells and cognitive radio networks because of the spectrum reuse of the unused spectrum holes by small cell users as secondary users. Moreover, D2D energy efficiency is found decreasing with increasing number of small cell UEs surrounding and increasing D2D distance because of strong interference. In addition, D2D SINR decreases with the increasing number of the wearable wireless patches used for instantly monitoring health information and increasing D2D distance due to the severe cross interference from multiple patches and fading on low powered signal from wearable patches with increasing the D2D distance. When the D2D nodes are highly mobile and found another small cell providing more than threshold SINR and high density, the D2D handover is significantly increased to provide better SINR and QoS to D2D communications. Furthermore, the data rate in multihop D2D is found decreasing with increasing mobility and increasing number of hops because of Doppler spread and multi-hop delay.

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