Next Generation Wearable Devices: Smart Health Monitoring Device and Smart Sousveillance Hat using Device to Device (D2D) Communications in LTE Assisted Networks

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Abstract: **-** Next generation wearable devices such as Smart health monitoring device and Smart Sousveillance hat, are capable of using wearable sensors for measuring physiological information, sousveillanace, navigation, as well as smart device to smart device communications. Smart health monitoring device collect and observe different health related information deploying biosensors and can predict health problems. Smart Sousveillance hat provides the brainwaves based fatigue state, training and sousveillance around the wearer. These wearable smart devices deploy the device to device communications in LTE assisted networks with D2D server and D2D Application server for spectrum utilization and cellular coverage, which make them portable, social, commercial and sustainable. Thus, the wearable device technology will merge with the smart communications besides the health and wellness. The simulation shows that LTE-D2D communications provides two times more energy efficiency than LTE cellular communications and significant LTE-D2D data rate with D2D-SINR and relative mobility of D2D devices.

Key-Words: Next Generation Wearable Devices, Smart Health Monitoring Device, Smart Sousveillance Hat, Device to Device Communications, Long Term Evolution, Assisted Networks

1. Introduction

The next generation wearable devices empower the human towards the real-time human's physiological information tracking along with the wireless communications, real-time location tracking and video surveillance. The next generation wearable device consists of the combo chip for the device to device (D2D) communications, cellular communications, WLAN and WiFi which provides the flexible wireless connectivity for communications. This enables wearable devices to exchange the health information and tracking, video surveillance and social networks which prepare them to become habitual, social motivation, long term utilization and provide sustainable services as compared to the existing wearable gadgets. The next generation wearable devices can bring the revolution in the consumer electronics products, consumer behavior and business ecosystem. The next generation wearable device networks consist of three different types of smart wireless devices for the device to device communications, which includes the next generation wearable smart sousveillance (inverse surveillance) hats, smart health monitoring devices and advance smartphones. The contemporary wearable smart devices are the bio-medical devices, smart glasses, smart watches and smart phones that collect and provide the partial health information, biometrics, real-time video streaming, object detection, recognition and tracking. However, the next generation wearable devices emphasize on the brain fatigues, detailed physiological information for health monitoring and preventive measures against diseases, intelligent device to device communications, gesture recognition, advance navigation, speech recognition and text-speech translation and vice versa.

In this paper, the smart wearable sousveillance hat is proposed, which is capable of detecting brainwaves for the brain's fatigue states and then train and manage the brain states. Moreover, the wearable smart health monitoring device also proposed to collect the different human physiological information from the different parts of human body, through wearable or implanted biosensors or handheld devices, and then display, store and communicate the digital biomedical information. The tiny biosensors are wearable or placed inside

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human body, which provides the physiological information such as body temperature, heartbeat, blood pressure, blood glucose level, respiration rate etc [1]. Furthermore, the smart sousveillance hat and health monitoring device have direct or indirect device to device communications capability and access to the internet like smart phones, so that the data transmission, data storage and real-time video-streaming can be done between these wearable devices, from wearable devices to the cloud and outer world. In other words, the real-time video and the human physiological data can be sent to other portable devices and stored in the cloud servers and storage device networks. This can be achieved only when the wearable devices are equipped with the renewable power supply or the wireless power supply, so that these devices can consume the required power for the massive amount of video and physiological data transmission during the device to device communications.

Body Area Sensor Networks (BASN) consists of multiple interconnected sensor nodes on, near, or within a human body, which together provide sensing, processing, and communication capabilities. BASN includes the physiological sensors, bio-kinetic sensors and ambient sensors to collect the different medical data, provide to the body aggregator to execute a multitude of functions, including sensing and data fusion, serving as a user interface, and linking BASNs to higher-level infrastructures [2]. The drawback of BASN includes the restriction of fewer sensor nodes, limited data range and bandwidth, limited redundancy and scalability, lack of cooperative Qos management and heterogeneous networks access. These are addressed by the smart health monitoring device which can connect with different body sensors or implanted sensors and isolated devices, collect massive video and medical data and execute sensor fusion, data mining, data exchange through D2D communications or LTE infrastructures and cloud storage.

The FreeGlass is the fifth generation Digital Eye Glass which has the great scope in the hands-free user wearable smart device. It provides the practical interaction, self-gesture-sensing and also avoids the one-sided effects of surveillance. This can make alteration from the surveillance culture to the sousveillance culture [3]. It can be used in the smart souseillance hat for 3D and 360 degree sousveillance coverage from the two FreeGlass equipped cameras, one in front and another at back side of the hat. Furthermore, multiple targets detection and tracking and advance navigation will be easier.

The next generation wearable devices including smart health monitoring device and sousveillance hat need to co-exist in the existing Long Term Evolution (LTE) networks and capable to communicate directly using Device to Device (D2D) communications inside the same cellular range. It provides better near field communication to the smart devices for different applications such as public safety, disaster management, sousveillance, health monitoring, navigation and commercial applications. The direct or indirect D2D communications between these smart devices provide the higher bandwidth, significant Qos, robust channel, power efficiency and higher spectrum utilization in the networks [4]. The D2D communications is also researched considering the cluster based WiFi-direct along with the LTE infrastructure, in which the D2D traffic goes through the WiFi cluster head selected from the LTE User Equipment (UE) mobiles to evolved Node B (eNB) [5]. The major issue is that the WiFi cluster head is unstable and it cause to the unreliable D2D communications bearer establishment, reconfiguration and data exchange. In this paper, the wearable smart devices are proposed as the evolved User Equipments (eUEs) with D2D enhanced signaling to communicate with the eNB before it established D2D link with another smart device. Moreover, the D2D gateway, D2D server and D2D application server are placed in the LTE networks for D2D dedicated services.

2. Problem & Proposed Solution

The problem is to formulate the next generation wearable devices, their network architecture and protocol to conduct D2D communications over the LTE networks. This enable the wearable devices for real-time health monitoring, brain fatigues, sousveillance, navigation, massive data transmission at higher data rate over the cellular coverage. However, these devices need to be supplied with sufficient power for D2D communications via renewable, chargeable or wireless power sources. The proposed solution includes the following aspects:

- Specifying and designing Wearable Health Monitoring Device to collect and track real-time human physiological information

- Specifying and designing Smart Sousveillance Hat for brainwaves and brain fatigue states, and 360 degree sousveillance

- Designing Network architecture for D2D communications between wearable devices in LTE-A infrastructure

- Modeling D2D-LTE Signaling and D2D Protocol for devices to Authenticate, QoS Determination and Charging Rate from D2D Server

- Simulation of LTE-D2D SINR and Data rate

2.1 Wearable Health Monitoring Device:

Wearable health monitoring device is the wrist wearable device which can collect all the health related information from different bio-medical sensor-processors or bio-medical devices via wireless connection and inform about the wearer's health condition. In other words, individual can store, monitor and conduct different medical tests itself even in the absence of doctor or lab-technician, using medical sensor-processors or devices, and determine whether individual has any symptoms of disease or not. This wearable device can keep the health monitoring of wearer by the WiFi, Bluetooth, Zigbee or IEEE 802.15.4 standard connection with the wearable sensors or implanted bio-sensors such as pressure sensors for respiration rate, blood pressure, Electrocardiograph (ECG) sensors for heart rate; ultrasonic sensors for body fat, pregnancy testing, body scanning; optical sensor for blood oxygen , electrochemical sensor for blood glucose level, alcohol, nicotine, drug, pregnant testing; thermal sensors for temperature and motion detecting sensor for calorie burnt; Electroencephalography (EEG) sensors for brainwaves; and strain gauge sensors for weight measuring as shown in Figure-1.The physiological information can be compressively collected as the information are correlated to each other and can be deployed during medical analysis and mining. The core collected physiological information can be forwarded to other smart devices and stored in the cloud by using the combo card for D2D, WiFi, WLAN and Cellular communications. The GPS receiver chip provides the real-time navigation of the wearer and device. It also allows real-time video calls, voice calls, conferencing, cloud services and Internet access.

The next generation health monitoring device can wirelessly connect up to fourteen or more isolated bio-medical devices as shown in figure-2. It can collect, display and transmit the physiological information, from the different bio-medical sensor-processor or devices to the cloud and other smart devices. It can connect spirometer, ECG, EEG, continuous noninvasive arterial pressure, infrared thermometer, human chorionic gonadotropin test digital kit, alco-sensor digital kit, urine test digital kit, glucometer, pulse oximeter, 3D ultrasonic scanner, strain gauge, fat analyzer, accelerometer and nicotine test device as shown in Figure-3. It also has capability to do medical data mining to detect and predict about different symptoms of diseases based on human physiological data analysis achieved from smart sensor processor or medical devices.

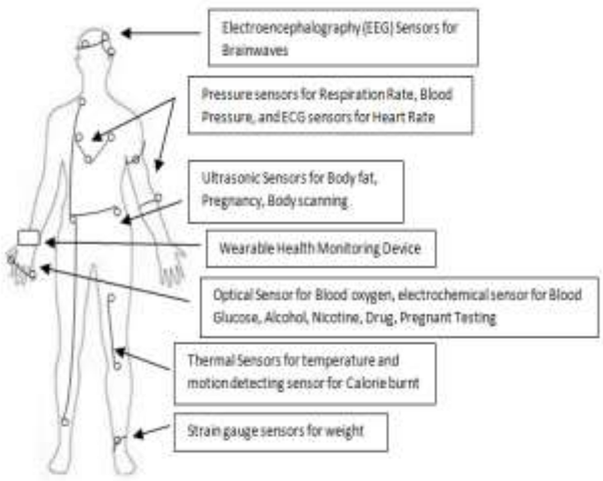

Fig.1 Wearable health monitoring system with monitoring device and different wearable sensors

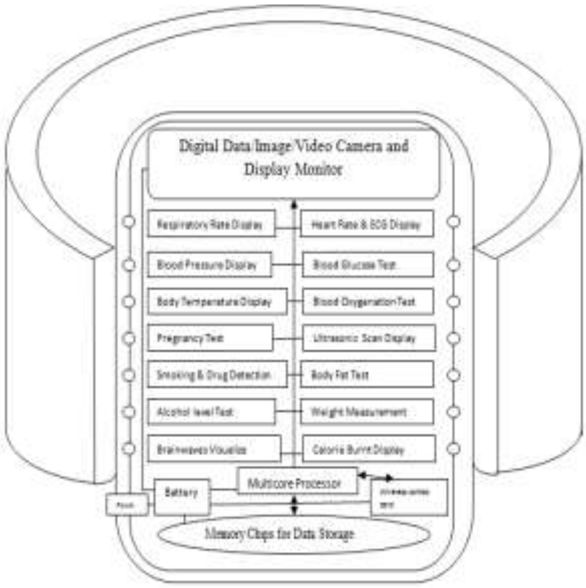

Fig. 2 Wrist Wearable Health Monitoring Device

The wearable health monitoring device has the WiFi and with sensor-procesor, digital meters and kits. It can measure and collect the physiological informaiton such as the respiratory rate, heart rate or beat, brainwaves, blood pressure, blood glucose, body temperature, blood oxygenation, pregnancy, ultrasonic 3D/2D body organs images, nicotine level, body fat percentage, alcohol level, body weight, drug test, calorie burnt, as listed in Table-I. The respiratory rate is measured using pressure sensor, optical sensor or spirometer which counts the number of breaths taken in one minute based on the chest expands and contracts. The heart rate is the heart beats per minute which is determined by Electrocardiograph (ECG) signal, measuring the interval between one R-wave and the next R-wave of the ECG signal, called the R-R interval. This can also be determined by the handheld wireless ECG devices or the ultrasonic sensor that detects the heartbeat and produces the perceptible replication. Similarly, the brainwaves are visualized by EEG sensors by detecting the electrical impulses in the brain to determine the feeling state of the brain which is described in the section of the smart sousveillance hat. Moreover, the blood pressure is determined by the oscillometric pressure sensor fitted in the punch to detect blood flow by the mean arterial pressure to calculate blood pressure. The blood pressure can be determined by the continuous noninvasive arterial pressure (CNAP) using an array of pressure sensors pressed against the skin over an artery, or the inverse of the pulse transit time (PTT) between two arterial sites [1], [2].

On the other hand, the body temperature is determined using contact sensor device like thermistor or the non contact sensor device like infrared emission thermometer from the various body parts including mouth, ear, armpit, rectum, forehead, bladder, skin, and throat. The blood oxygenation is determined using reflectance pulse oximetry on the feet, forehead, and chest which determines the saturation of oxygen in the blood measuring both oxygenated and deoxygenated hemoglobin at the peripherals. The blood glucose level is determined digitally by using the gluco-sensitive meter which can measure the amount of glucose from strips with blood sample. In addition, the entire body's ultrasonic scanning is conducted by using the wearable ultrasonic sensor networks which basically generate the high frequency sound waves and receive their echoes from the fluid and soft tissue, soft tissue and bone creating the 3D and 2D. This can be used to detect the any internal physical problem in tissue, bone, cells and organs as

TABLE I
WEARABLE HEALTH MONITORING DEVICE MEASURES, MEASURAND AND SENSOR DEVICES

Health Measures	Measurand	Sensor /Devices
Respiratory Rate	Chest expands and contracts, forced expiratory volume, peak expiratory flow	Pressure sensor / Spirometer
Heart Rate or Beat	Electrical activity of the heart, R-R interval in Electrocardiograph (ECG) signal	ECG /Magnetometers
Brainwaves Visualizer	EEG sensors placed on specific sites on the scalp to detect and record the electrical impulses with different frequencies within the brain	EEG sensors
Blood Pressure	Systolic (peak pressure) and diastolic (low pressure), Inverse of Pulse Transit Time (PTT), measuring blood volume in finger using a light transmitter and receiver, pressure sensor fitted in the punch to detect blood flow	Oscillometric sensor or Continuous noninvasive arterial pressure (CNAP)
Blood Glucose	Blood-glucose levels	Glucometer
Body Temperature	Measuring own temperature, radiated heat from the measured brightness or spectral radiance of an object	Thermistor or Infrared Thermometer
Blood Oxygenation	Monitoring a patient's Oxygen saturation on the feet, forehead, and chest by measuring both oxygenated and deoxygenated hemoglobin	Pulse Oximeter
Pregnancy Test	Tests work by binding the HCG hormone in urine to a monoclonal antibody and an indicator/pigment Molecule	Accelerometer /HCG Test Kit
Ultrasonic Scanning	High frequency sound waves and their echoes from the fluid and soft tissue, soft tissue and bone create Images	3D Ultrasonic Scanner
Smoking Test	Nicotine in saliva and urine.	Nicotine Test Device
Body Fat	Percentage of body fat	Ultrasonic Fat Analyzer
Alcohol level Test	Blood alcohol content detection from Breath	Alcosensor
Weight measuring	Body weight or load generates compressive force over sensors	Strain Gauge Pressure/ Piezo Sensors

Drug Test	Drug-specific chromatic chemical test strips with urine sample	Urine test Kit with drugs
Calorie Burnt Test	Worn around the waist, arm or thigh, measure the motion of the body	Wearable Accelerometers

well as, to care child and baby during the pregnancy period. The different phases of pregnancy can be tested by binding the Human Chorionic Gonadotropin (HCG) hormone in urine to a monoclonal antibody and an indicator or pigment molecule [1]. This can be elaborated digitally using ultrasonic and accelerometers.

Furthermore, the smoking status is determined by Nicotine or Tobacco level which is based on the residual metabolite of nicotine, also known as cotinine test device for urine testing. The body fat is determined in terms of percentage using ultrasonic fat analyzer. The body weight is measured by using the strain gauge or piezo sensors which detect the force on the sensor. The alcohol level detection is done using the alcosensor which detects the platinum oxidization level by any alcohol in the breath air to produce acetic acid. The Drug test and its dosage can be conducted by testing blood or urine using the drug-specific chromatic chemical test strips and processing that using digital kit. The calorie burnt is measured using wearable accelerometers, worn around the waist, arm and thigh, measures the calorie consumed based upon the motion of the body.

2.2 Smart Sousveillance Hat:

Smart Sousveillance Hat is the wearable hat equipped with the tiny cameras for video surveillance or sousveillance around the hat wearer and the Electroencephalography (EEG) sensor networks to determine the fatigue mind of the hat wearer by analyzing brainwaves detected by EEG sensors. The term 'sousveillance' refers to 'sensors or cameras borne by people' whereas 'surveillance' refers to 'sensors or cameras affixed to the environment'. In sousveillance, the camera is affixed to the wearer and thus there is the relative motion between the camera and the background objects, as the wearer moved, which does not happen in surveillance [3]. The designed smart sousveillance hats are the smart cowboy hat and smart baseball hat as illustrated in the Figure-4. It can provide the front and back side 3D video sousveillance and facial recognition in the same video monitor just in front of wearer face. It provides the hands free camera like in a smart glass but also protects the space between nose and eyes and the burden on nose. It also provides WiFi, WLAN, D2D and Cellular communications using the combo card and GPS navigation. Moreover, it also determines the fatigue feeling state of the brain and associated behaviors of the wearer based on brain waves so that wearer can do mind makeup and management by changing brainwaves and training as shown in Table-II. Similarly, other people can also determine the fatigue feeling state of the wearer

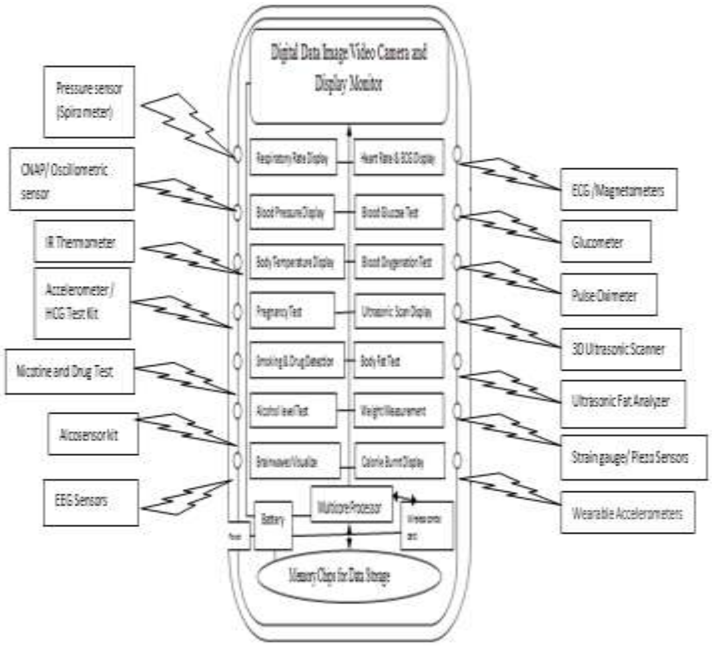

Fig. 3 Wearable Health Monitoring Device with other wireless smart sensors or devices

before and after training, through mind sharing module via the D2D or cellular wireless communications between smart sousveillance hats or with the health monitoring device or smart phone, and thus prevent from the unpredictable accidents.

There are five different types of brainwaves which are gamma (ϒ), beta (β) with sub-bands, alpha (α) with sub-bands, theta (θ) and delta (δ) as illustrated in Figure-5. These brainwaves have different characteristics frequencies which illustrate different brain's fatigue feeling states, associated behavior and effects of mind make up as illustrated in Table-II. The increased beta (β) brainwave wave is associated with increasing alertness, arousal and excitement whereas the decreased β associated with increasing fatigue level. Similarly, the alpha (α) brainwave indicates the relaxed and effortless alertness mental state, relaxation and low arousal. The increased alpha wave means an increased mental effort to maintain vigilance level. The theta (θ) brainwave refers to sleepy, working memory, cognitive performance, drowsy and tired with the loss of attention with and a variety of mental states. The delta (δ) brainwave is the lowest brain activity associated with deep stages of sleep, high fatigue, drowsiness, wide array of disorders and decrease arousal level with slow wave brain activities. The research has shown that the significant increases in α and (θ + α)/β, as well as the decrease in θ/α, are associated with the increasing fatigue state [6].

Smart sousveillance hat basically consists of EEG sensors to read and visualize the electrical impulses of human brain known as brainwaves to determine the wearer's fatigue states. It also includes the GPS receiver for navigation, two tiny 3D video cameras for video sousveillance, display monitor in front of face connected with hat, wireless combo chip, processor, memory and battery. The processor is the heart of the smart hat which control and execute the designed five major application modules as shown in Figure-6. These applications are the bainwave visualization and mind make up, mind sharing and reader, 3D video sousveillance, real-time navigation, incident and location reminder, and WiFi, D2D and cellular access to other smart hats, smart health monitoring device and smart phones. It can also fascinate to store the photos, video, voice to text conversion and vice versa, geo-locate the current location and navigation towards the destination. The brainwaves fatique and sousveillance can be deployed in the soldier's hat to exchange the mental fatigue of soldiers and track the soldier's battlefield position for situation awareness.

Smart sousveillance hat provides the real-time situation awareness using two 3D video cameras coverage, one at the front side of the hat and another at the back side of the hat so that the wearer can observe what is happening in the surrounding environment. It can also detect the facial properties and track down based on object in the video. In addition, it consists of a sensor network with electroencephalography sensors, one on the forehead, two above the forehead and two above ears. These sensors detect and record the electrical activity and waveforms with different frequencies. The different modes of brain fatigue such as active, sleepy, tired, frustration, temper, upset etc are determined based upon the frequency ranges, spatial distributions and different status of brain functioning and it can be trained and controlled which is listed in Table-II.

TABLE II
BRAINWAVES FREQUENCY RANGES

Types of Brain waves	**Frequency**	**Fatigue or Feeling States**	**Associated Behaviors**	**Effects of Mind make up**
Gamma (ϒ)	31-120 Hertz	accepted wisdom; integrated opinion	high-level information processing, compulsory	not known
High Beta (β_1)	19-30 Hertz	vigilance, awareness, anxiety	Intellectual, scholar activity, arrangement, forecast	induce alertness, but may be confrontation, altercation
Mid Beta (β_2)	16-18 Hertz	thinking, self awakens and environment	mental activity, observant, Alert	increase mental ability, focus, attentiveness
Low Beta (β_3)	13-15 Hertz	relaxed yet focused, incorporated	Poor Sensory Response refers to inattention, confusion	Raising Sensory Response can make relaxed, enhanced conscientious, skill
Relaxed and Alert Alpha (α_1)	11-12 Hertz	relaxed, not nervous, but not drowsy; calm, cognizant	centering, curative,	mind/body connection, relaxation
Slow Alpha (α_2)	8-10 Hertz	relaxed, not agitated, but not drowsy; peaceful	inner-wakefulness of self, meditation,	mind/body amalgamation, equilibrium, rest
Theta (θ)	4-7 Hertz	perceptive, recall, desire, metaphors, tired; sensation	innovative, aware; but may also be diverted, imprecise	either induce nomadic, daydream-like state or improve meditation
Delta (δ)	1-3 Hertz	yawning, dreamless sleep, reverie, unaware	not affecting and not assiduous	sleepiness, trance, deeply unperturbed states

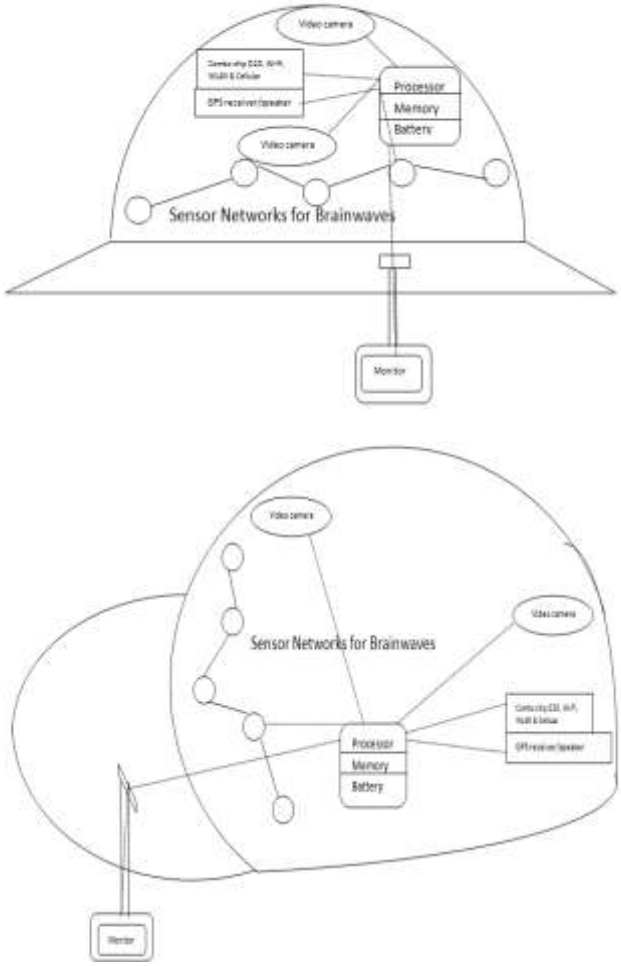

Fig. 4 Smart Sousveillance Hats: Smart Cowboy Hat and Smart Baseball Hat

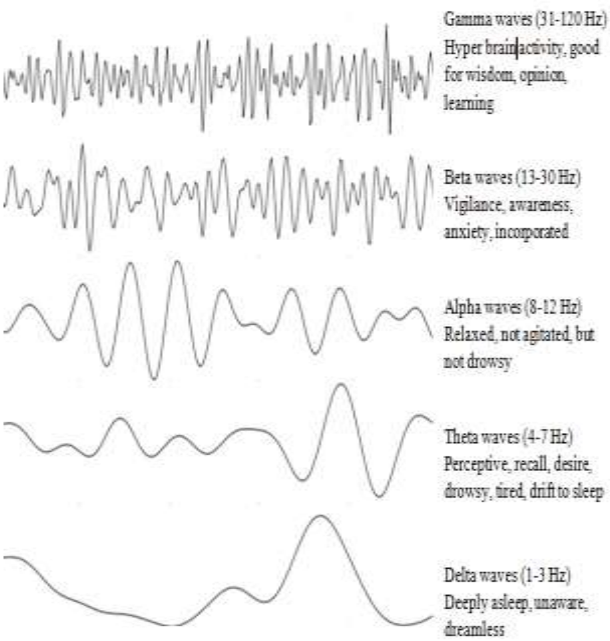

Fig. 5 Different Brainwaves

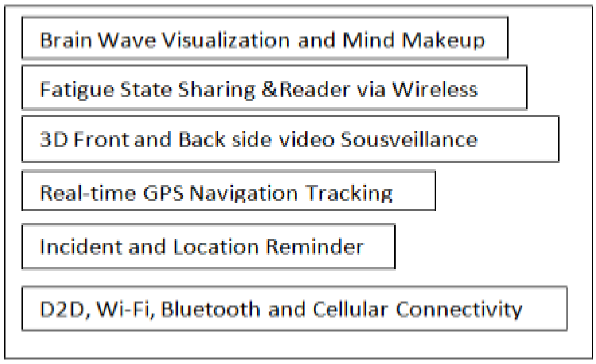

Fig. 6 Smart Sousveillance Hat Applications Module

2.3 Device to Device (D2D) Communications:

The next generation wearable smart devices such as health monitoring devices and smart sousveillance hats have D2D communications capability, by virtue of which these smart wearable devices are used as User Equipments (UEs) which can communicate each other in the short range, without using the data transmission through the base station from the cellular infrastructure. The D2D communications allow the peer to peer short distance communications between transmitter and receiver devices with the good channel link, QoS and energy efficient connectivity. In other words, D2D communications provide very quickly, reliable and robust link avoiding the packet transmission delay which yields the significant network performance during the huge video file transmission in the surveillance, complex medical data exchange in the health monitoring, public safety services during the natural disaster. Likewise, D2D communications coexist in the cellular infrastructure sharing the spectrum bands which guides to the optimum spectrum utilization, divesting at the similar time in the cellular network. Furthermore, even though there is the direct communications in WLAN using unlicensed ISM bands like WiFi-direct for very short range, but there is not the licensed band being used in cellular network for D2D communications for longer range, which is addressed by 3GPP in Long term Evolution (LTE).

3GPP has initiated D2D communications in LTE release-12, recommending the licensed spectrum for innovative public safety or commercial proximity services (ProSe) communications. The Prose communications include the ProSe Evolved Universal Terrestrial Radio Access (E-UTRA) Communications, ProSe-assisted WLAN direct communications between only two User

Equipments (UEs) and ProSe Group Communications or ProSe Broadcast Communications [7]. In ProSe E-UTRA Communications, the path could be established either directly between the ProSe-enabled UEs using E-UTRA, or routed via local evolved Node B (eNBs). Similarly, ProSe-assisted WLAN includes the direct communication path establishment directly between the ProSe-enabled UEs using WLAN. The D2D communications using the next generation wearable smart devices can be efficiently deployed using the ProSe E-UTRA Communications, ProSe-assisted WLAN communications and ProSe Group Communications for health monitoring, public safety operations, navigation and sousveillance. The next generation wearable smart devices are either the ProSe-enabled Public safety UE that supports ProSe procedures as well as capabilities specific to Public safety, or ProSe-enabled non-public safety UE that supports ProSe procedures but not capabilities specific to public safety. ProSe-enabled UEs are discovered by using the ProSe direct discovery which is the network independent procedure to discover other ProSe-enabled UEs in its vicinity by using only the capabilities of the two UEs with release-12 E-UTRA technology. The second is the EPC-level ProSe discovery which is the network authorized process by which the Evolved Packet Core (EPC) determines the proximity of two ProSe-enabled UEs and informs them of their proximity.

D2D communications is categorized as in-band and out-band communications based upon the allocation of the radio spectrum. In-band D2D communications uses the cellular spectrum for both D2D and cellular links to take the high control over cellular or licensed spectrum. In underlay D2D communication, cellular and D2D communications share the same radio resources whereas the overlay communications allocates the dedicated cellular resources. The underlay D2D communications is considered in this paper, when D2D range is more than range of WiFi. The major issue of the in band D2D is that it may induce the interference between the D2D UEs and cellular UEs, which can be addressed by deploying the high complexity resource allocation methods along with the higher computational overhead. On the other hand, out-band D2D communications uses the unlicensed spectrum to eliminate the interference between D2D UEs and cellular UEs, however it paybacks an extra channel interface and adaptation with other wireless technologies such as WiFi direct, ZigBee, Bluetooth [5]. This can be addressed by making cellular networks as controlled network and D2D as autonomous. The major issue of the out-band D2D is the unrestrained characteristics of unlicensed spectrum. The out-band D2D can be efficiently deployed by the UEs with two wireless interfaces to LTE and WiFi which provide the instantaneous access to both D2D and cellular communications.

The D2D communications for next generation smart wearable devices has to address some major challenges such as the adaptation with existing legacy LTE-A technology, business, social media access and security. D2D communications need to co-exist with the LTE-A infrastructure and hand held UE devices using mobile Peer to Peer (P2P). In other words, D2D communications is done using bluetooth, WiFi-direct, LTE-A direct and non 3GPP-direct. It supports the direct communications between the 3GPP and non 3GPP devices using the proposed network architecture with D2D gateway, D2D server and D2D application server. Moreover, D2D communications need to provide significant Qos for eUE subscribers for huge video data transmission, public safety operations and reasonable price charging for different services so that subscribers can be attracted. It also needs to provide instantaneous access to the social media and cloud services. Furthermore, D2D communications need to be strictly secured and monitored by D2D gateway and D2D application server. The security schemes need to address the vulnerabilities such as spoofing, tampering, repudiation, replay, man-in-middle attack, denial of service, and privilege access. For P2P based D2D authentication, the integrated key based friendly device verification and packet encryption, based on the location information and pre distributed key can be deployed [8].

The D2D communications is also studied using the cluster based WiFi-direct along with the LTE infrastructure in which there is no significant change in LTE protocols [5]. The D2D traffic flows through the WiFi cluster head selected form the LTE UE mobiles, to eNB and cluster head provides the opportunistic and timely schedule. The major issue in this research is that cluster head can be any selected UE mobile, which may not be stable, robust and sustainable. This can yield the unstable and unreliable D2D communications bearer establishment, reconfiguration and data exchange. The another issue of this scheme is that UE has to complete the double authentication and security check, WiFi security check with cluster head and security mode check with eNB. If the cluster head changed immediately, then it should be performed again before establishing bearer. Therefore, the D2D adjustment within the existing LTE infrastructure adding some D2D application specific servers is proposed as shown in figure-7.

2.3.1 Network Architecture for proposed D2D Communication

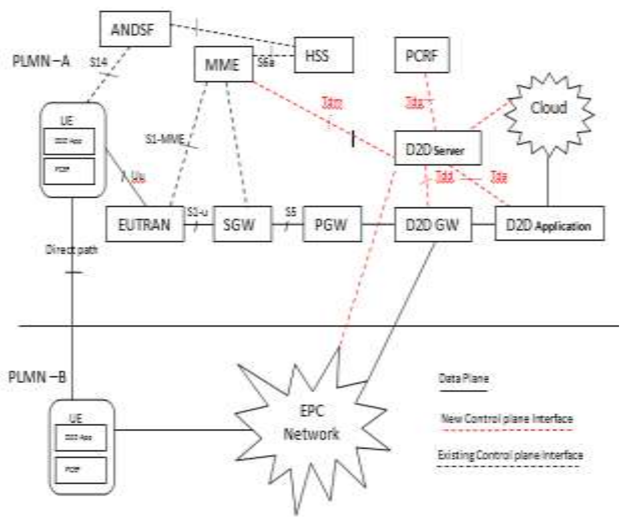

Fig. 7 LTE Assisted Network Architecture for D2D communications

The functions of different network components of the proposed LTE-A enabled D2D communications from figure-6 are mentioned below:

eNodeB (eNB) provides RRC establishment, mode selection between peer to peer and cellular links based upon the distance between devices and signal to interference noise ratio. It also provide IP header compression, encryption of user data streams, UL control channel granting, P2P link granting with decoded CRNTI.

Home Subscriber Server (HSS) stores the updated current location of the D2D eUEs, by sending the subscriber information to MME in the Diameter protocol with the update location acknowledge message.

Mobility Management Entity (MME) provides the NAS signaling and security, updated location as well as area tracking information and the list of neighboring buddy devices to D2D server, PGW and S-GW selection, handovers, eUEs authentication, bearer management.

Serving Gateway (S-GW) provides the local mobility anchor point for inter-eNodeB handover; downlink packet buffering and support network service requests, lawful interception, accounting on user and Qos granularity.

Packet Date Network Gateway (PDN-GW) provides the eUE IP address allocation, packet filtering, and PDN connectivity, UL and DL service-level charging for eUEs, D2D-GW connectivity for D2D server and application server.

Access Network Discovery and Selection Function (ANDSF) is a component in EPC for 3GPP mobile networks, to assist eUE to discover non-3GPP access networks such as Wi-Fi or WIMAX and provide the eUE with rules policing the connection to non-3GPP networks.

PCRF (Policy and Charging Rule Function) is the logical node that defines the minimal bandwidth, Qos requirement, dynamic session management and service charge for D2D communications over D2D server and D2D gateway. The service charge depends upon the activation/deactivation, initiation/termination, duration and amount of data transferred, QoS via E-UTRAN, inter-operator communication and inter-operator signaling.

D2D Gateway is the D2D proxy server for D2D-ID authentication, D2D IP allocation, packet filtering and D2D application server connectivity. It also provides D2D packet buffering and initiation of D2D network-triggered service requests.

D2D Server registers and tracks all D2D enabled eUE devices and store the updated D2D application services. It executes the Proximity service based bandwidth enforcement and QoS determination for D2D applications based upon the updated information from eUE, MME and PCRF. It also determines the UL and DL service level charging, gating and rate enforcement for D2D communications. It can communicates with other

Pro-Se peers in other PLMNs to provide the assistance information such as group ownership, pre shared secrets. Thus, it co-ordinates and co-operates to provide the D2D services for both 3GPP and non 3GPPP evolved packet core.

D2D Application server provides the requested D2D application services to authenticated D2D devices for public safety groups, social media and health monitoring. It store the eUEs and users profile, list of buddies, eUE's discovery setting, and D2D cookie tracking. It has direct interface with D2D server and eUE through D2D GW. The D2D applications include the big video data streaming, real-time health information exchange received from the wearable or implanted sensors, brain states reader and sharing for fatigue awareness, video calls, sousveillance, navigation and location tracking, multiple devices in D2D mesh connectivity for conference, cloud based services (data storage, software and hardware sharing).

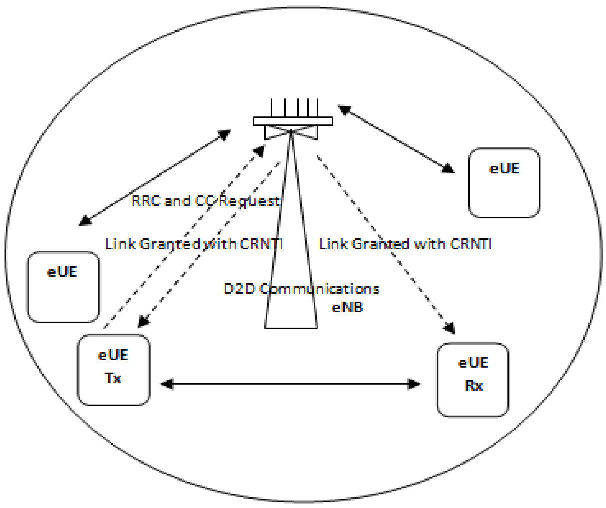

Fig. 8 D2D Communications in LTE cell

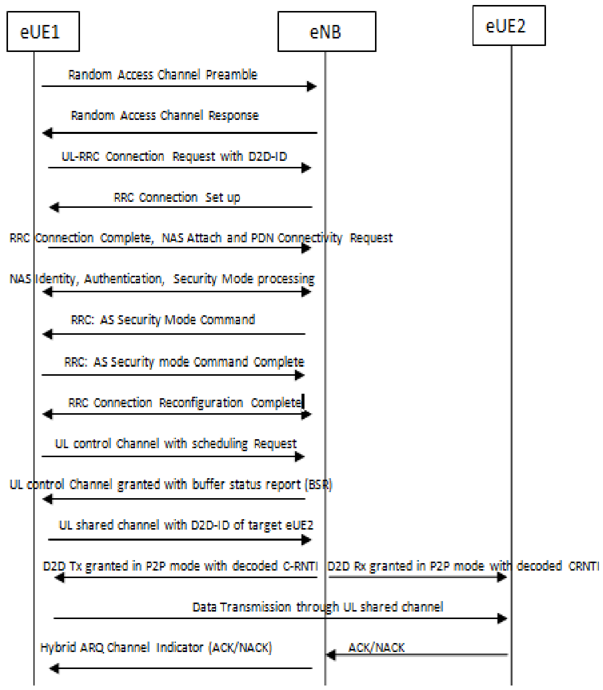

Fig. 9 D2D enhancements in standard LTE-A signaling

2.3.2 D2D Enhancements in LTE Signaling

The next generation wearable smart devices are eUEs, which can connect within the same PLMN or cell. The eNB is D2D manager which provides the D2D resource allocation and power control in the first phase then the peer discovery procedure and the peers tuning in the second phase [7]. For the LTE assisted D2D communications between two smart devices eUE1 and eEU2, the eNB has to execute the Radio Request Connection (RRC) connection establishment, Network Attach Service (NAS) identity and authentication, PDN connectivity, security mode complete, RRC reconfiguration, Uplink control channel establishment, and Uplink shared channel granting for D2D Tx (Transmitter) to make the P2P communications with D2D Rx (Receiver) [9], [10], [11]. Then, D2D Tx can transmit data to D2D Rx respectively until both the eUEs move away from the coverage of the eNB. The same procedure need to be repeated whenever the D2D peer is failed or the eUEs move from the coverage of one eNB to another eNB. First of all, eUE1 requests to eNB with the preamble sequence for the physical random channel access, then eNB provides the temporary Cell Radio Network Temporary Identifier (C-RNTI) in the random channel response which is used as the general C-RNTI till the eUE1 exist inside the coverage of the same eNB. The C-RNTI is also used to uniquely identify UEs at the initial random access procedure, radio resource control connection, channel scheduling, coding or decoding of the physical downlink control channel, shown in Figure-8. Each eUE can produce the D2D-ID deploying the specific algorithm over the Mobile Subscriber Identification Number (MSIN) which is the 10-digit global unique number. The self D2D-ID generation capability of eUE basically co-operates the eUE Tx to generate the pool of D2D-IDs of its buddies and D2D-ID of the specific eUE Rx. When the eUE1 requests for the uplink RRC connection to eNB, it sends the D2D-ID of the eUE1 and then eNB responds with RRC link set up [9]. Then, eUE1 sends the RRC connection complete along with the initiation of the Network Access Service (NAS) attachment and PDN gateway connectivity to MME through eNB. The MME established bearer to SGW, also update the location of eUEs in HSS and forward that to D2D server [10]. Then SGW creates the bearer to PGW and thus the IP address is allocated for eUE by PDN-GW. The MME has to set up the bearer between eNB to SGW and eNB has to establish the security parameters for security mode procedure of eUE so that the ciphered data are transmitted between eUE and eNB on the security mode complete and then the RRC is reconfigured by eNB as shown in Figure-9.

TABLE III
D2D MAPPING TABLE

eNodeB ID	Source MSIN (10 digits)	Source C-RNTI (8 digits)	Source D2D – ID (6 digits)	Destination MSIN (10 digits)	Destination C-RNTI (8 digits)	Destination D2D –ID (6 digits)
eNB21	8743378401	54623742	432539	1435038231	55903456	213415
eNB21	856456712	57648593	483245	2637489433	45769034	154836

When the uplink channel control with scheduling for uplink data transmission request come up from eUE1 to eNB, then eNB has to set the uplink channel control with the active Buffer Status Report (BSR) which generally execute the single-bit Scheduling Request for the requested uplink channel control [11]. Once BSR is assigned to eUE1 then it sends the D2D-ID of the destination eUE2 in the MAC control element along with logical channel ID, in the BSR request. The eNB has to validate the C-RNTIs with corresponding D2D-IDs at the initial channel access so that there is no duplication and replay. This is conducted by eNB by allocating C-RNTIs and D2D-IDs of the requesting eUEs, in the peer mapping table with C-RNTIs and D2D-IDs of their corresponding destination eUEs respectively as per D2D mapping table as shown in Table-III.

When the D2D channel allocation is granted by eNB between eUEs, then eNB has to inform both eUE transmitter (eUE1) as well as eUE (eUE2) receiver with the corresponding decoded C-RNTI regarding the spectrum region in which they are using for the D2D data communications as shown in Figure-7. The eNB allocates the non occupied resource blocks of certain number of subcarriers for D2D communications, which is used by the D2D Tx (eUE1) when it searched for the D2d Rx (eUE2), by adding pilot signal and other resources such that there will be additional spectrum space for the D2D Rx (eUE2). The pilot signal has certain power based upon the range of D2D connections which the eNB has permitted in its coverage. Once, the pilot signal from the D2D Tx (eUE1) is received by the D2D Rx (eUE2) then it responds to eNB and the D2D peer discovery is successful. The eNB can also allocate the resources for frequent and consequent requests based upon the underlay and overlay principle which has been assigned at eNB. The D2D Rx (eUE2) reply with Ack/Nack message to eNB in which Ack means the data received successfully and Nack means not received and need to be retransmitted again. The eNB advances this message to the D2D Tx (eUE1) through the Physical Hybrid ARQ Indicator Channel as shown in Figure-8. Then, the D2D Tx (eUE1) and D2D Rx (eUE2) can communicate directly without sending data through the eNB until they move away from the coverage of the eNB.

2.3.3 D2D Protocol for eUEs to Authenticate, QoS Determination and Charging Rate from D2D Server

When the LTE assisted D2D communications between two wearable smart devices eUEs is to initiate, it has to do signaling among various network components in the LTE assisted network as shown in above Figure-9. The eUE has to establish RRC connection successfully with the eNB as described in the D2D enhancements in LTE-A signaling in Figure-8. Then, the eUB executed the authentication, integrity and security control through eNB by passing different signaling in between MME, HSS, SGW and PGW with various bearers as described earlier in D2D enhanced signaling which is the preliminary level [7]. There is another round of authentication for eUE with D2D–GW, before it accessed to D2D application server and establishes the D2D communications with another eUE. The D2D-GW authenticates the MSINs and D2D-IDs of the all eUE Txs and eUE Rxs based upon the database provided by the D2D Server, prior to the initiation of D2D network-triggered service. The D2D Server register MSINs and D2D-IDs of all D2D enabled eUE devices, updated D2D application services, determines the QoS and the service level charging for D2D communications and send to eUEs, once it is requested. The D2D server also forwards the Qos, service type and charging enforcement to D2D application server. Finally, the D2D application server responds the Ack signal to both D2D server, eUE Tx and eUE Rx confirming the requested D2D service has been provided between eUE Tx and eUE Rx as shown in Figure-10. The LTE assisted D2D services can be related to the public safety groups, social media, health monitoring, sousveillance, cloud services and other commercial services.

3. Simulation Results

In simulation, the LTE-D2D SINR is compared with LTE UEs SINR and D2D-LTE Data rate is analyzed with LTE-D2D SINR and the LTE-D2D relative

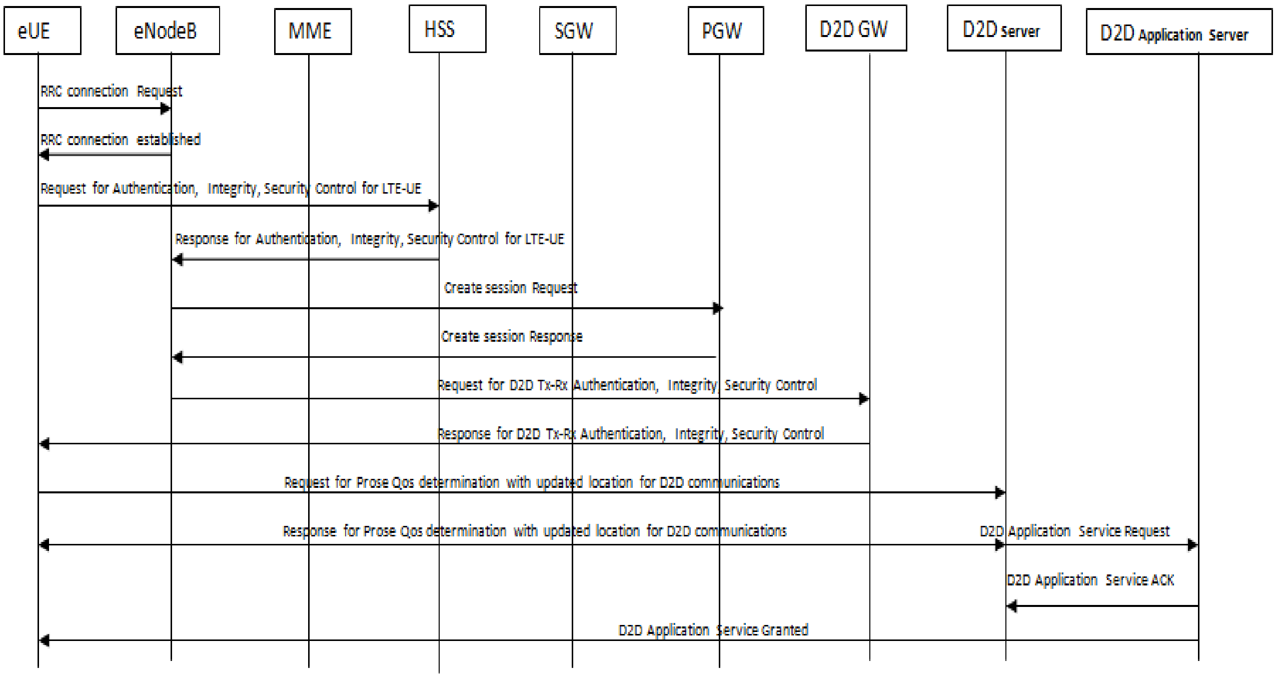

Fig. 10 D2D Communcations protocol in LTE Assisted Network

mobility. The signal to interference noise (SINR) in LTE-D2D communications is the ratio of the power gain by D2D transmitter with the channel gain in D2D pair and the co-channel interference from adjacent eNBs, the Additive Gaussian noise and the interference from serving eNB. Similarly, the SINR in LTE cellular UE users is the ratio of the transmit power gain of eNB with the channel between eNB and cellular user and the co-channel interference from adjacent eNBs, the interference from D2D

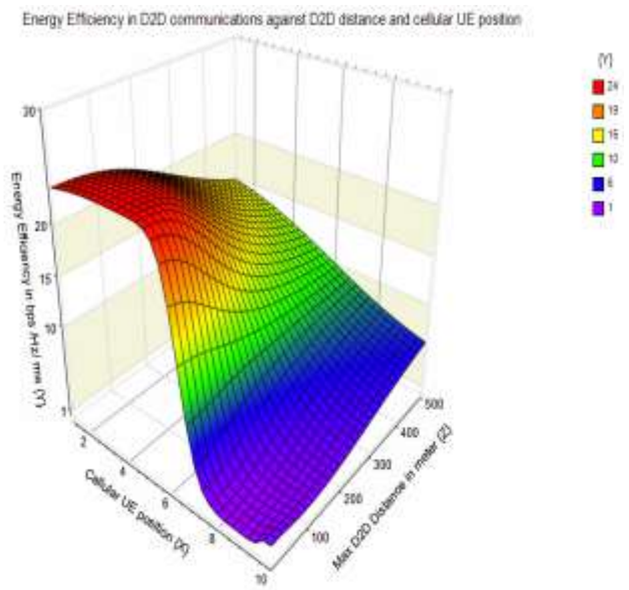

Fig. 11 Energy Efficiency in LTE-D2D Communications

transmitter, and the Additive Gaussian noise. Furthermore, the SINR in LTE-D2D communications also based on the maximum D2D distance between D2D enabled devices and the position of the cellular UE with which the D2D link shares with eNB cellular resources orthogonally either time or frequency, especially in the uplink physical resource blocks. The Figure 11 and 12 has shown the position of the cellular UE on x-axis, maximum D2D distance on z- axis and the SINR or energy efficiency on y-axis. From Monte-Carlo simulation, it is achieved that maximum SINR is 24bps/Hz/mw for four UEs sharing uplink resources when the max D2D distance is 300m. The D2D's SINR decreases as the number of UEs and D2D distance both increases as illustrated in

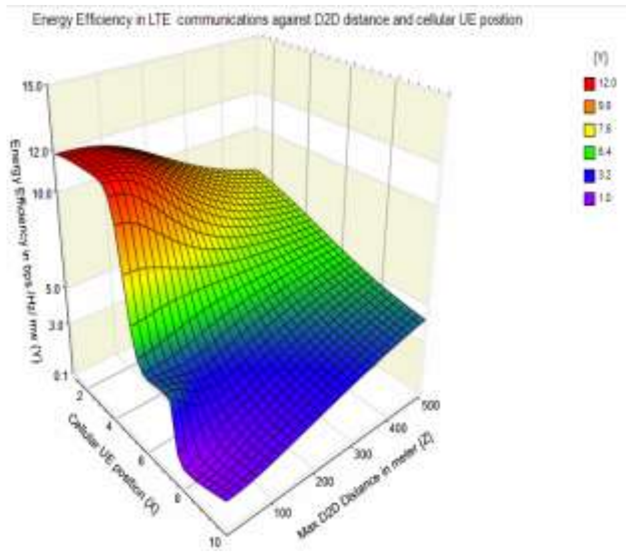

Fig. 12 Energy Efficiency in LTE Communications

Figure-11. It is found that the SINR efficiency is significantly reduced as the number of sharing UEs in uplink with D2D is more than six UEs. On the other hand, SINR is also plotted for cellular UEs against max D2D distance and the position of the cellular UE. It is achieved that maximum SINR is 12bps/Hz/mw for four UEs sharing uplink resources when the max D2D distance is 300 m. The cellular UE's SINR also decreases as the number of UEs and D2D distance both increases as illustrated in Figure-12. The simulation shows that energy efficiency in LTE-D2D communications is twice of the energy efficiency than LTE cellular UEs even though there are interferences from eNBs, co-channel eNB and uplink sharing UEs. In this paper, the wearable heath monitoring device and sousveillance hat device are considered with sufficient renewable or chargeable power supply for LTE-D2D communications. The major reasons behind significant SINR efficiency in LTE-D2D over LTE UEs include the licensed spectrum in D2D communications, close proximity between D2D enabled devices and power saving by adjusting power labels. In addition, interference is reduced by direct D2D transmission of data using allocated spectrum and not transmitting data through eNB except the request for D2D link and D2D service authentication.

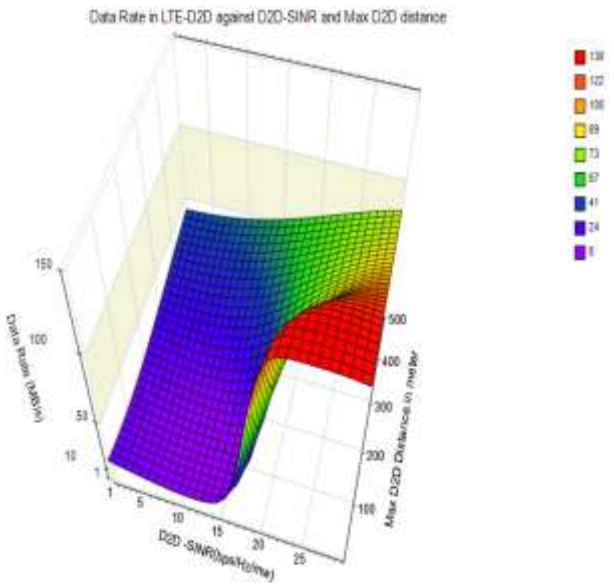

Fig. 13 LTE-D2D Data Rate against D2D-SINR in LTE-D2D Communications

The data rate in LTE-D2D communications is increased with higher D2D-SINR and lower D2D distance. In other words, there is certain loss in SINR with increasing D2D distance which reduces the data rate in D2D communications. This means energy need to be increased by beam-forming as the D2D distance increases so that data rate can be significantly maintained. The simulation shows that the D2D-SINR of 15-30 bps/Hz/mw can give the D2D data rate of 138 Mb/s at the D2D distance of 300m and 89 Mb/s at 300-500 m then gradually decreased with decreasing D2D-SINR as shown in Figure-13.

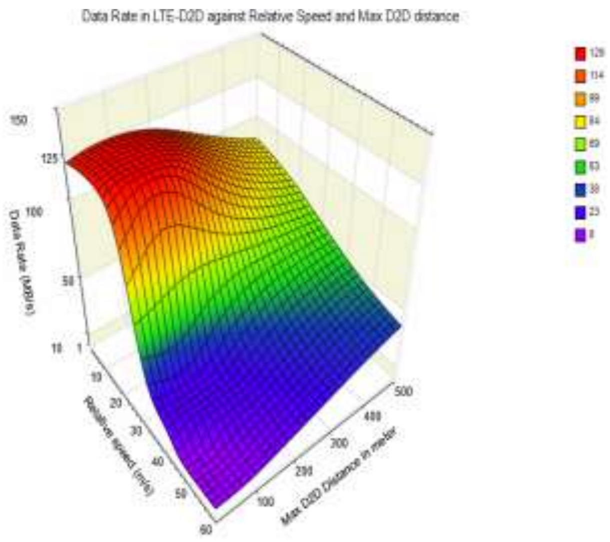

Fig. 14 LTE-D2D Data Rate versus Relative Speed in LTE-D2D Communications

The data rate in LTE-D2D communications is increased with lower relative mobility speed of D2D devices and lower relative D2D distance. When the relative speed of D2D devices increased yielding the increasing relative D2D distance then the D2D data rate is reduced because of the severe Doppler spread. The simulation shows that the relative D2D speed of 10-25 m/s can give the D2D data rate of 129 Mb/s up to the D2D distance of 400m and 84 Mb/s at 400-500 m and then gradually decreased with increasing relative speed as shown in Figure-14. The D2D data rate can be improved in higher relative speed for the fast Doppler spread channel by deploying adaptive modulation and channel coding scheme [12].

4. Conclusion

The next generation wearable devices such as wrist held health monitoring device and smart sousveillance hat, have D2D communications capability in LTE assisted networks using in-band and out-band spectrum. This can bring revolution in advance wearable device technology because of the scope of wearable devices for integrated public safety and social services beyond bio-medical applications. In addition, the wearable devices become more interactive, habitual and long term in utilization. From simulation, the energy efficiency in LTE-D2D communications is found twice of the energy efficiency than LTE cellular UEs even though there are interferences from eNBs, co-channel eNB and uplink sharing UEs. The LTE-D2D data rate is significantly increased with higher D2D-SINR and lower D2D distance. The LTE-D2D data rate is also significantly increased with lower relative mobility speed of D2D devices and lower relative D2D distance.This concurs that LTE-D2D with wearable devices are more reliable, realistic and robust than LTE-UEs. In future, the wearable device technology will revolve human by wearable intelligent chips as special brain, guide for disabled people and protector for civilian in natural disaster or soldier in battlefield.

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