Indian Journal of Science and Technology, *Vol 10(33), 10.17485/ijst/2017/v10i33/112749, September 2017*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

A Survey on Traffic Evacuation Techniques in Internet of Things Network Environment

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Abstract

Objectives: System capacity has become a major concern while machine-to-machine (M2M) traffic evacuation has become a paramount interest due to the traffic congestion as well as overloading at the radio access and core network of the human-to-human (H2H) and machine-to-machine (M2M) communication framework of the 5G network. We therefore review the various solutions to the evacuation of M2M traffic with the aim of eliminating the said congestion. **Methods/Statistical Analysis**: We review various technologies including the low range radio technologies, and the long range wide area technologies available for internet of things (IoT) traffic otherwise called M2M traffic for decongesting the network and alleviating the M2M communication degradation effect on H2H communication. We also considered the application of massive MIMO in Heterogeneous networks for massive evacuation of the M2M traffic leading to greater separation of the H2H and M2M traffic and the eventual reduction of the network congestion. **Findings:** The application of massive MIMO for backhauling in macro cells for M2M traffic evacuation and which also provides 40 per cent capacity improvement via small cells placed indoor in a spatial densification heterogeneous network (HetNet) was considered as a good option for solving the above problems. **Application/Improvement:** A comprehensive survey on the use of the various techniques for traffic evacuation was not presented in the literature which we achieved in this paper.

Keywords: Internet of Things, Small Cell, H2H, LPWAN, M2M

1. Introduction

The numbers of things connected to the internet is becoming exponentially large leading to a new idea of Internet commonly termed the Internet of Things (IoT)[1,2]. IoT ecosystems are made up of smart objects with tiny and highly constrained physical devices in terms of memory capacity, computational capacity, and energy autonomy as well as communication capacities. These smart objects which includes anything ranging from washing machine, television, motorized window blind to industrial machines, cars, hospital equipments, humans with implanted medical devices etc are expected to be equipped with micro-electromechanical (MEMS) systems which are embedded into the objects enabling them to communicate and interact with their environment[3]. In the paradigm of IoT, devices and machines are also expected to communicate with each other creating trillions of devices communicating with each other. However, present communication infrastructure is unable to cope with such humongous scale communication due to the challenges of infrastructural bottleneck. Massive MIMO (Multiple input and Multiple Output) which leverage on large numbers of antennas to improve spectral efficiency, network capacity and energy consumption is a good 5G candidate for enhancing machine-to-machine (M2M) communication. In this paper, our aim is to look at the various 3GPP emerging communication technologies for evacuating M2M traffic otherwise known as MTC (Machine Type Communication) and finally look at how massive MIMO a feature of 5G technology enhances M2M communication for the MTC IoT application.

It is estimated that billions of devices will be connected to the Internet by year 2020, and a reliable and secure

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bidirectional communication is important for IoT connected devices to make data routing between the devices seamless, this connectivity will enable businesses, governments as well as individuals to make data driven decisions in real time and for this paradigm to be realized, wireless communications technologies are expected to evolve to meet new challenges that may arise[4]. IoT technology enables machine-to-machine (M2M) and machine-to-people communication on a large scale and most of this communication will be made by Wi-Fi, Bluetooth, ZigBee and Radio Frequency Identifier (RFID) which are short range radio technologies that works in the unlicensed frequency range for indoor and home environment where the peripheral IoT devices or nodes are characterized by low energy consumption, relatively low transfer rates and mostly machine-to-people communication[3]. Other connectivity that support large amount of traffic and are used for evacuating M2M traffic resulting from the aggregation of the extremely high number of smaller data flow will be made by long range wide area networks such as the NB-IoT, LTE-M, LTE-cat 0, LTE-A and the 5G networks among others which are characterized by high reliability, low latency and high transfer rate that are mostly M2M communication.

A description of how NB-IoT addresses key IoT requirement including its deployment in GSM and the LTE was done by the authors in[5,6] without considering other narrow band low-power technologies such as LPWA, ZigBee etc[7]. Reviews the IoT connectivity landscape including low-power Wi-Fi, low-power wide area (LPWA) networks, ZigBee and the various 3GPP cellular MTC devices that can be used for evacuating IoT data traffic. The need for network densification to solve the ever growing high data rate communication and M2M data traffic evacuation is discussed in[8-10] offering solutions for reducing traffic congestion and overloading at the radio access and core network, in particular suggested the use of mobile small cells that can be mounted on cars, buses and train to solve the problem. Finally, in the deployment of massive MIMO for evacuating aggregated M2M/IoT data traffic authors of[11] suggested that the upgrading of base stations (BSs) and eNBs with large number of antenna elements can serve 40 percent more M2M devices in a single cell while[12] suggested the deployment of massive MIMO for tackling the mixed-service M2M and H2H traffic challenges in the uplink of a cellular network. However, a comprehensive survey on the use of the various techniques for traffic evacuation was not presented in the literature which we set out to achieve in this paper.

The rest of this paper is divided as follows; section II is a review of the various low range radio technologies for M2M communications, section III deals with M2M architecture, while section IV looks at the various cellular network, long range communication technologies for evacuating the aggregated traffic, section V is on network densification and massive MIMO for M2M communication while we conclude in section VI.

2. Low Range Radio Technologies

The IEEE 802.15 group of standards are used for wireless personal area networks (WPAN) for different applications in the field of Internet of Things (IoT) communication including 802.15.1 for Bluetooth, 802.15.4f for active battery powered Radio-Frequency Identification (RFID), 802.15.5g for Smart Utility Networks (SUNs) for monitoring the Smart Grid, 802.15.4e for industrial applications. Also the IEEE 802.15.4 physical (PHY) and medium access control (MAC) layer was recently complemented by the IP-enabled IETF protocol stack, the IETF 6LoWPAN enabling the transmission of information wirelessly using internet protocol version 6.

The most popular enhancement to the 802.15.4 suite or standard is the ZigBee; those enhancements makes ZigBee very useful in the implementation of the Wireless Sensor Networks (WSN), a communication platform for intermittent, low data rate internet of things connectivity[13]. Such enhancements include authentication with network nodes, encryption for security and data routing/forwarding capability that allows the achievement of mesh networking. In the field of internet of things and smart cities, ZigBee is available in pre-developed applications such as; Smart energy for home energy monitoring, Healthcare for medical and fitness monitoring, Home automation for control of smart homes, Building automation for commercial monitoring/control of facilities and Retail services for shopping related uses and many more.

3. Machine-to-Machine (M2M) Communication Architecture

There are three basic component of M2M communication, these are the M2M domain, Network domain and the Application domain while quoting the European

Telecommunications Standards Institute (ETSI) considers M2M network architecture as consisting of five parts which are; Devices, Gateway, M2M area network, Communication network and the Application. The five however form the three interlink domains of M2M area domain consisting of M2M area network and the M2M gateway, the communication network domain made up of various wired/wireless networks such as XDSL, 3G etc and the application services domain. The three correspond to the three domains as stated by[14,15].

According to the ESTI for the purposes of interoperability defined a horizontal services platform for M2M communication based on Services Capability Layer (SCL) which is accessible through open interfaces making it possible to set up IoT services that is independent of the technology used. Thus an M2M device can run M2M application with a local SCL where it is connected directly to the Network Domain through the Access network as shown in Figure 1.

The Device can also be connected via the M2M gateway to the Network Domain as shown in Figure 1. Thus the M2M Network provides interconnection between the Devices and the gateways. The emerging M2M applications communicates by having access to wireless and cellular networks such as ZigBee, Bluetooth, WLAN, LTE/LTE-A etc. Table 1, shows the various M2M communication technologies, their area of applications and the typical data rate.

Though M2M data transmission is minute in size, but due to the billions and trillions of devices involved and the frequency of accessing the network, they have the capacity to overload the network and affect the

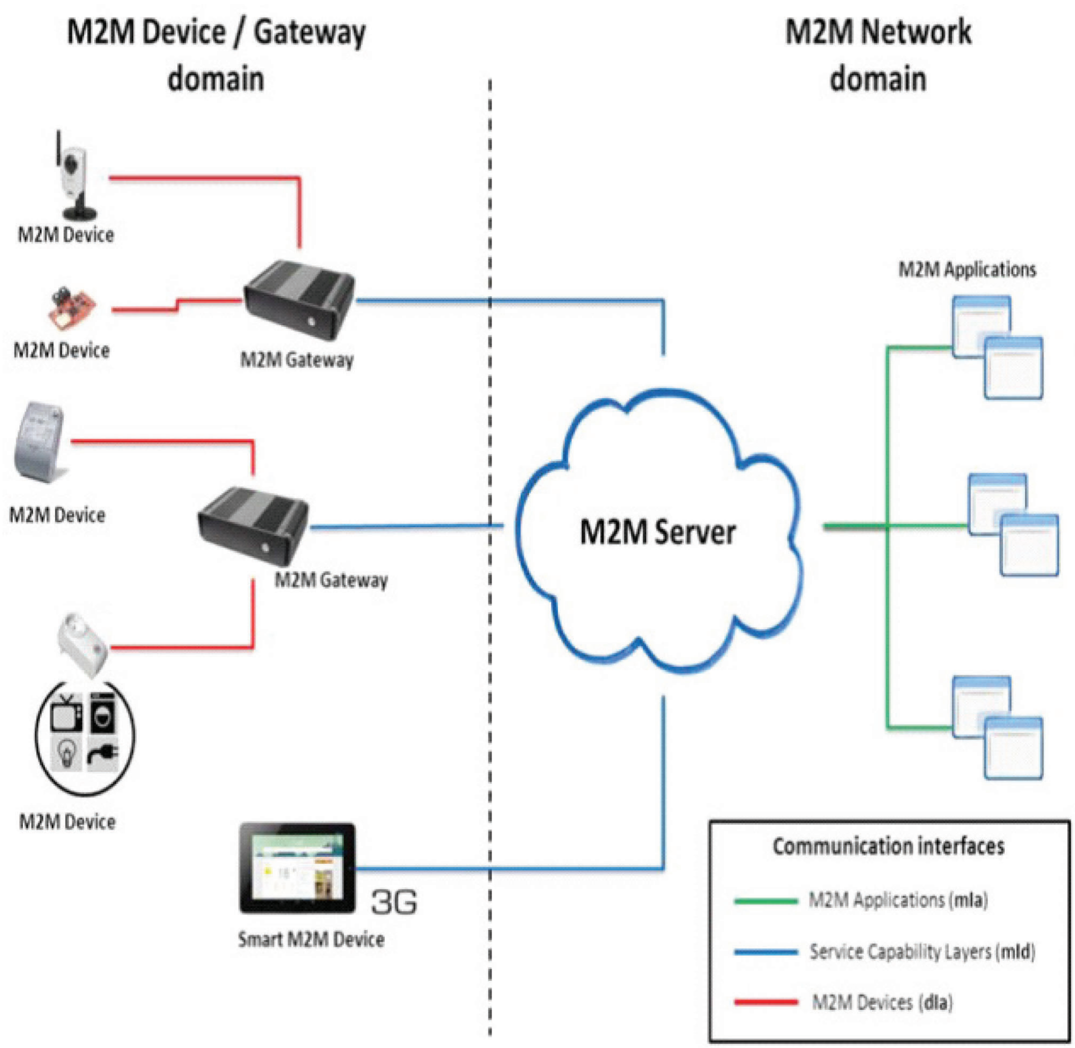

Figure 1. Machine-to-Machine Architecture.

Table 1. Technologies for M2M Area Network

Standard	Area	Rate (Mbps)	Typical Application
SRD (Short range Device)	Personal	<0.02	Wireless audio, RFID
UWB (Ultra-Wideband)	Personal	>100	Video, File sharing
Zig Bee	Personal	<0.25	Sensors monitoring
Bluetooth	Personal	3.0(V2.0)	Music file sharing
Wi-Fi	Local	108(802.11g)	Water metering
Fem to cell	Local	>7.2	Cellular phones

Human-to Human (H2H) communication. Due to the massive increase in M2M devices and their influence on H2H communication, cellular network operators and the 3GPP are discovering new ways to enable new technology features handle this massive increase. One of such feature is the massive MIMO which is a future wireless technology with capacity to handle higher numbers of concurrent users than conventional existing cellular network technologies can handle.

4. Long Range Wide Area Technologies

According to[5], there are two alternatives for IoT applications connectivity based on long range wide-area coverage, these are the cellular networks (3G, 4G etc) and the low power wide-area network (LPWAN) application radio access technology which leverage on low power wide area networks and mainly require deep/wide coverage, low power consumption and massive connections. 3GPP has three of its LPWAN technology. According to[16], 3GPP is working to optimize (cost, power and coverage) cellular technologies for the small, intermittent data transmissions common in IoT peripheral nodes introduced the LTE-M (Enhanced Machine-Type Communication for LTE), NB-LTE-M (Narrowband LTE MTC) and the NB-IoT.

4.1 LPWAN

The LPWAN is basically characterized by low cost devices, low data rate and little amount of data exchanged, long battery life, primarily designed for M2M application where cellular M2M systems are not efficient or optimized. Some of the proprietary LPWAN solutions in the market include Amber wireless, LoRa, NWare, Weightless, Sigfox etc. Though LPWAN operates in the unlicensed spectrum, LoRa Alliance, Sigfox and Weightless are preparing LPWAN standards towards operating in the licensed spectrum.

Although, used for long range connectivity, it does so to complement cellular connections rather than replace it. Some of the challenges of LPWAN in the long range traffic evacuation environment includes its unsymmetrical uplink and downlink connectivity, also is the challenge of scalability requirements for large scale IoT deployments as a result of spectrum congestion which are anticipated from other spectrum user competition. These challenges are as a result of the use of unlicensed spectrum which may be overcome when the licensed spectrum LPWAN version as stated above come into use.

4.2 LTE-M (LTE-MTC)

LTE-M delivers a suite of features, as part of the 3GPP Release 12 and 13 standards. Some of the features includes lowering power consumption, reducing device complexity/cost, and providing deeper coverage to reach challenging locations (e.g., deep inside buildings). The LTE channel consist of resource blocks of about 230 kHz of spectrum, and LTE-M is part of the 1.4 MHz block, made up of six resource blocks, it is more power efficient as a result of its extended discontinuous repetition cycle (DRX), meaning that the endpoint can communicate with the tower or the network on how many times it will wake up to listen for the downlink. The advantage of LTE-M for M2M communications is that a cellular carrier only has to upload new baseband software onto its base stations to turn on LTE-M. LTE-M has a little higher data rate than NB-LTE-M and NB-IoT, and is able to transmit fairly large chunks of data therefore it can be used for applications such as city infrastructure, tracking objects, utility metering, and wearable[17].

4.3 NB-LTE-M (Narrowband LTE MTC)

Another overlay of existing LTE structure, like the LTE-M, this technology is created by allocating existing resource blocks to M2M IoT traffic by using smaller channels to which enables the making of simpler receivers. NB-LTE-M proposes to re-farm GSM by using a single 200 KHz resource block. Rather than using 1.4MHz spectrum and six blocks. NB-LTE-M uses only one LTE resource block, making it unique in that it gives the user an effective throughput of about 200 kbps downlink and 144 kbps uplink.

4.4 NB-IoT

Beyond LTE-M and NB LTE-M the 3GPP has also designed the new cellular technology which scale even further down in complexity and power to address the low throughput IoT applications referred to as the NB-IoT. NB-IoT is the last of the 3GPP Rel. 13 proposal which is not based on LTE, but instead on a DSSS (Direct Sequence Spread Spectrum) modulation similar to the new version of Weightless-W (which is a set of LPWAN open wireless technology standards for BS/IoT devices M2M communication). The mode of complexity is even simpler than NB-LTE-M. According to, this radio technology is designed specifically for machine-type communication since the cellular networks was designed and optimized for high quality voice and data communication. The NB-IoT radio technology is used to address the ultra-low-end sensor segment which places very little demand on throughput and QoS. NB-IoT is a self-contained 200 kHz bandwidth carrier that can be deployed and enabled using new network software on an existing LTE network, thereby resulting in rapid time to market. The challenge of NB-IoT is the difficulty with ease of deployment since it is not a part of LTE, it therefore required to operate in a side band using different software which may be costly or be deployed in deprecated GSP spectrum, According to the low data rate and the latency-tolerant nature of the machine type communication (MTC) traffic has made it possible to enable the operation of NB-IoT applications on Global System for Mobile Communications/General Packet Radio Service (GSM/GPRS) networks, this is important for IoT in Africa and developing nations where the deployment of LTE is not widespread. However, it was also identified that much revenue potential can be harvested by network operators who migrate MTC traffic from 2G to LTE networks.

While the NB-IoT can be deployed in an LTE carrier with the use of one physical resource block (PRB) of 180 KHz, the 200 KHz carrier of the GSM can be replaced with the NB-IoT. It can also be used in the guard-band of the LTE carrier or in a standalone format within the LTE Figure 2. NB-IoT has massive IoT devices support capability with the use of one PRB in both the uplink and downlink channel as it can support more than 52,500 UEs per cell, and with its ability for multi-carrier operation, a cell with multiple NB-IoT carriers will offer more UE traffic evacuation connectivity.

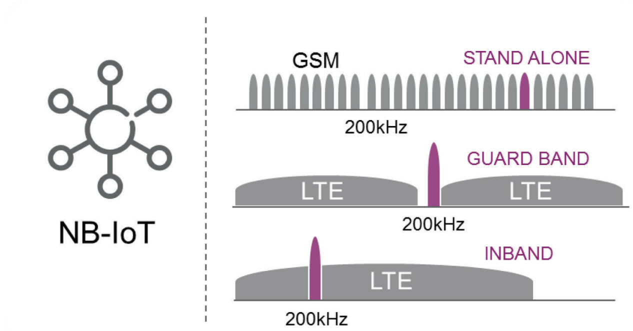

Figure 2. NB-IoT deployment scenarios.

The efforts of researchers are also moving towards the implementation of IoT requirements through the fifth generation (5G) wireless systems. 5G is expected to provide innovative network features such as support for MTC communication, small-cell (femtocell, Picocells, relay cell etc) deployments for network densification, interoperability by seamless integration with both 3GPP and non-3GPP access technologies for enhanced reliability and coverage as well as provide softwarization and virtualization of network entities and functionalities, where the problem of the traditional concept of physical cellular subscriber identification module (SIM) has resulted in the limitation for large-scale tiny IoT device. This could be resolved by replacing the physical SIMs with e-SIMs which will allow "over the air" provisioning of network connectivity. In the scenario described above, 5G will play a key role in the IoT M2M communication where M2M communications means that UEs, machines and various devices can directly communicate with each other with little or no human involvement[18,19]. Table 2 shows comparatively the features of NB-IoT with LTE-M and the next generation 5G where it compares favorably in all fronts.

Table 2. Comparison table of M2M

	LTE – Evolution LTE-M Rel. 13	**Narrowband NB-IoT**	**Next Generation 5G**
Range (outdoor)	< 11km	<15km	<15km
MCL	156dB	164dB	164dB
Spectrum	Licensed (7-900MHz)	Licensed (7- 900MHz)	Licensed (7-900MHz)
Bandwidth	1.4MHz or Shared	200KHz or Shared	Shared
Data Rate	<1Mbps	<150Kbps	<1Mbps
Battery life	>10 years	>10 years	>10 years
Availability	2016	2016	2025

5. Network Densification

Today the macro cell network scalability has reached its peak, aside from the optimization of HSPA+ that has nearly matched LTE in performance (the evolution of HSPA+ is towards LTE), the expensive nature of deployment of macro cells makes it cumbersome for operators to further optimize their network[20] and adding more bandwidth often has prohibitive high costs.

To solve the above challenge, operators and researchers has looked at various directions for the required high data rate and throughput for the high data rate hungry applications, particularly the evacuation of the aggregate IoT data. Such solutions are classified within the following broad groups.

- Exploiting the use of MU-MIMO antenna technology for enhancing spectral efficiency[21].
- Taking advantage of the use of higher spectrum frequencies in small cells and Wireless Mesh Networks for data offloading.
- Enhance spatial reuse with small cells through network densification for the achievement of Heterogeneous network (HetNet).

The dominant driver for growth in wireless network capacity has been identified as:

- Increase in number of base stations (BS).
- Increased use of radio Spectrum.
- Improvement in link efficiency.

In order to appreciate the impact of the above factors on the capacity of a cellular network, let us consider the equation

$$R < C = M\,(W/n)\,\log_2[1+ S/(I+N)]$$

This equation is based on the capacity of an additive white Gaussian noise (AWGN) channel. This equation define the upper bound of the rate of transmission of a user in a cellular network where

W = Base station Signal bandwidth
n = (load factor) denote the number of users sharing the given base station
M = (Spatial multiplexing factor) in the number of spatial streams between BS and users devices
S = is the desired signal power
N, I = are the noise and interference power respectively
C = Network capacity

From the above, we see that using additional spectrum leads to a linear increase in data capacity as a result of increase in signal bandwidth W, n the load factor can be decreased by cell splitting (spatial densification) which reduces path loss and increases S. M is increased by using a larger number of antenna both at the base station and user devices.

These parameters for wireless transmission capacity improvement as jointly represented by the equation above can be classified under a common name of "network densification". Thus network densification is a combination of spatial densification (which increases the ration M/n) and spectral aggregation (which increases W). Spatial densification is achieved by implementing massive MU-MIMO (user device and base station for multiplexing gain or base station alone for diversity gain) and also by increasing the number of BS per geographical area. Spectral aggregation requires the use of larger amount of spectrum spanning the 500MHz up to the millimeters wave bands (30-300GHZ). It should be noted that spatial densification and spectral aggregation (network densification) will not have the desired QoS and QoE if it is not complemented by backhaul densification which link the BS to the core network.

5.1 Massive MIMO

5G requirement for IoT connectivity is diverse and less is understood about the role of massive MIMO technology in the evacuation of IoT data traffic till now. When MIMO goes massive quite a number of things happen. First, the asymptotic of random matrix theory set in with many consequences as things that were random before, begins to look deterministic. For example, the distribution of the singular values of the channel matrix approaches a deterministic function. Very tall or very wide matrices also begins to be very well conditioned, as dimensions become large, some matrix operations such as inversions can be done fast by the use of series expansion techniques. Also, thermal noise is averaged out and the system becomes limited majorly by interference from other transmitters[22-24] while simple linear signal processing approaches such as matched filter (MF), zero forcing (ZF) etc pre-coding/detection can be used to achieve these advantages. Other advantages or benefits of massive MIMO include reduced latency, large spectral efficiencies, simplification of the MAC layer, the use of low powered inexpensive components, cell edge performance improvement as well as robustness to intentional jamming[25,26]. The phenomenon leading to the above advantages for massive MIMO are the channel characteristics known as favorable propagation and channel hardening. Favorable propagation condition is the mutual orthogonality between the various UEs vector channels. Mathematically we say the channel offer favorable propagation if channel vectors $\mathbf{h}_k$ are pair-wise orthogonal i.e.

$$(\mathbf{h}_i^H \mathbf{h}_j) = \{0, i, j = 1, 2\ldots.., k, \text{ and } i\ j\} \text{ and}$$
$$(\mathbf{h}_i^H \mathbf{h}_j) = \{\ ||\mathbf{h}_k||^2\ 0, k = 1, 2,\ldots..K\}$$

We also say that the channel offers asymptotically favorable propagation if

$$(\mathbf{h}_k^H \mathbf{h}_j) \textbf{ as } M$$

where k j and M is the BS transmit antenna. The favorable propagation occurrence is the most significant property of the i.i.d. Rayleigh fading channel in the massive MIMO system[27].

Favorable propagation allows massive MIMO distinguish each UE in the spatial domain and beamform to each of them using linear precoder in the downlink as shown in Figure 3.

Massive MIMO with its various advantages and features is an enabler for the development of future mobile as well as fixed broadband networks particularly the 5G which is expected to be energy efficient, robust, use spectrum efficiently and be secure. Based on these, massive MIMO is seen as a corner piece in the connectivity of

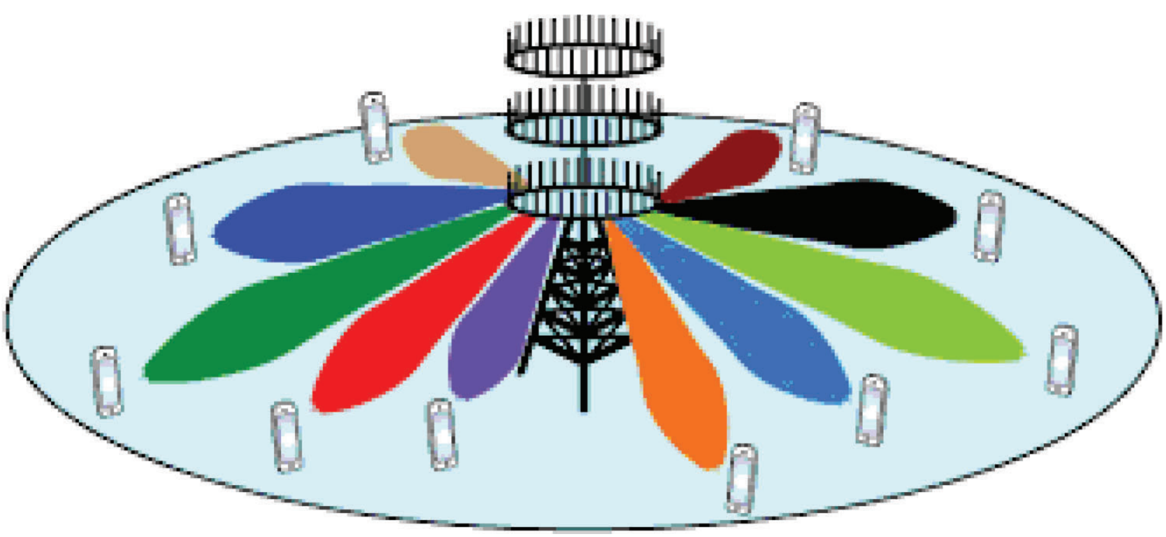

Figure 3. Massive MIMO setup.

Internet of Things (IoT), Internet of People with clouds etc[28]. One of the main issues in M2M communications is the limited channel capacity of the core network. The cellular network technologies are upgraded to facilitate H2H communications. On the other hand, M2M users are also increasing rapidly as M2M communication is providing ubiquitous computing environment towards the "Internet of Things". Enormously increasing number of M2M users may degrade the performance of H2H communications. According to upgrading the BS or eNBs with Massive MIMO can serve 40 percent more M2M devices in a single cell. The paper also explained that if massive MIMO is installed in eNBs of UMTS and LTE/LTE-A then it is much possible to reduce degradation caused by M2M devices to H2H communication on those cellular networks. According to, the uplink mixed service communication challenge of concurrently delivering narrowband services to MTC devices and wideband services to UEs above can be solved by applying the use of massive MIMO in BSs. It stated that it is computationally complex to treat MTC devices as regular wideband services UEs as the physical resource blocks (PRBs) scheduling in a 5G dense network is not a trivial task especially when we consider retransmissions and uplink synchronization procedures in such networks, the authors then suggest the clustering of MTC devices where each cluster share the same time-frequency PRB under the assumption that a physical narrowband shared channel (PNSCH) is provided for use by the MTC devices. This way and with the ability for multiple PNSCH channel per massive MIMO cell, the mixed services challenges are resolved and more importantly, the cell capacity for M2M traffic evacuation is expanded and enhanced.

5.2 Heterogeneous Network (HetNet)

HetNet is a network densification technique of overlaying multiple tiers of mobile communication network cells. For example a three-tier HetNet is formed by the addition of Picocells and Femtocells in the coverage of Microcells, and according to[29] a small cell is a low-power and low-cost radio BS that is designed to provide better cellular coverage within the Macrocells coverage and these include Picocells, Femtocells, trusted WLAN cells, and relay nodes Figure 4 which is defined in LTE Release 10/11. Small cells (SCs) are used in HetNet for increasing network capacity through the network densification technology since the deployment of Macrocells with its attendant challenges including cost of site is more expensive than deploying SC.

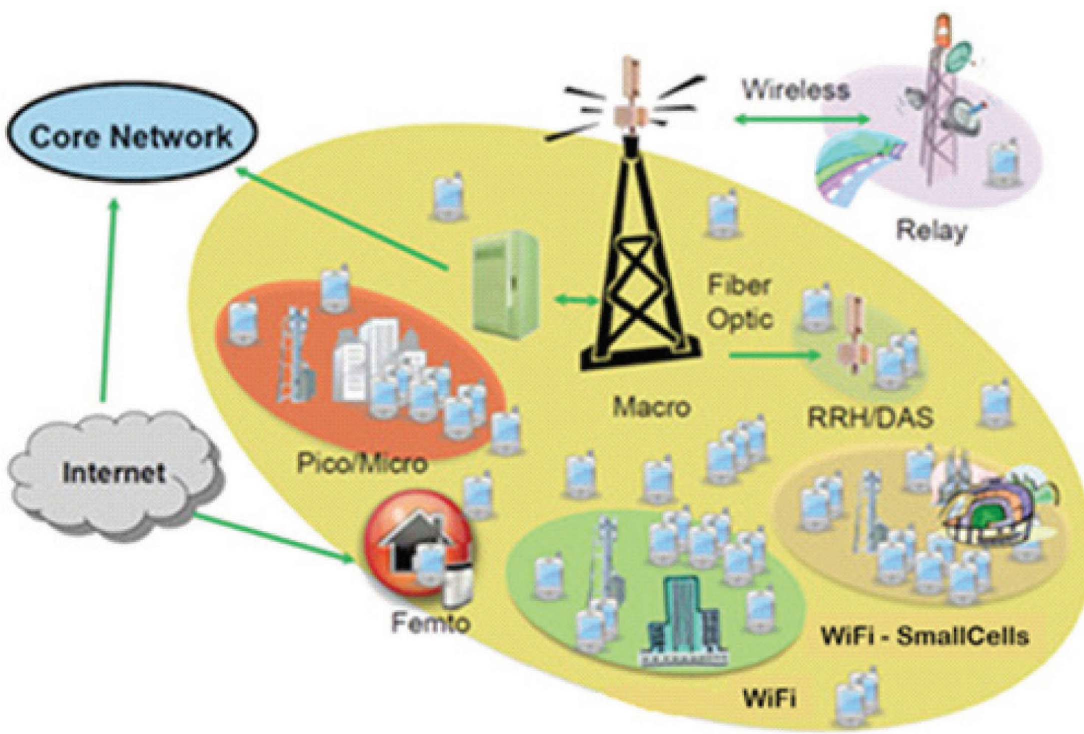

Figure 4. Heterogeneous Networks.

Small cells achieve increase in network capacity by offloading data traffic from the macro-cells. Small cells have two basic access policy which are the closed Subscribers group (CSG) and the open subscriber group (OSG) modes. While CSG mode allows access to subscriber group members only, the OSG provides services for any user in its coverage though both access policies can be mixed. SC deployment can be configured to transmit on a co-channel frequency with the Macrocells or on a dedicated carrier frequency. Dedicated carrier frequency operation avoid inter-sc interference but limits the available bandwidth the SC can access and is also less efficient than co-channel deployments, however though co-channel operation provides better frequency utilization it suffers from inter-sc interference that result in handover and coverage challenges for mobile UEs particularly in SC with CSG access in which UEs cannot connect to the cell with strongest signal. Generally speaking OSG in better than CSG from a network capacity enhancement point of view and also from the point of view of users QoE/QoS. While it may be expected that QoS will degrade by moving from CSG to OSG, this might not be so and generally does not happen particularly for CDMA uplink where the Femtocell performance is much better for the OSG since strong interferers are handed off, mitigating the near–far problem (Femtocell, past, present and future). However the closer the OSG SC is to the Macrocells BS, the smaller is the resulting SC coverage due to MC power dominance leading to poor or inefficient MC data offloading as UEs tend to connect to MC rather than to SC.

As the distance between the base station MC and the SC continue to reduce as a result of spatial densification resulting in reduced path loss, microcell UEs would connect to the SC with the smallest path loss and would transmit with a lower UL power thus allowing load balancing and UL interference mitigation thereby improving network performance. Resolving the above power difference challenges in co-channel Macrocells and microcell has led to new cell selection methods been developed for cell splitting gains in hotspots. There are 3G, LTE and LTE-A versions with LTE RIO featuring such capabilities as cell range expansion (CRE) and enhanced inter-cell interference coordination (eICIC) for providing efficient Macrocells data off-loading and managing the inter-sc interference issues enumerated above.

Due to its small size, Femtocells are not used outdoor or for mobile UEs but targeted at static UEs providing 80% of today's data traffic carried indoor, since most MTC devices are static indoor it could be used for M2M traffic evacuation to the macro-cell. LTE Femtocell provides Dual connectivity (DC) capabilities that ensures macro-cells provide voice service for a UE and outsource its data service to the Femtocell SC. Dual Connectivity (DC) is not used for macro-cell and microcell small cells as it is not compatible with the eICIC features of such SC since eICIC tries to make macro-cells invisible to small cell UEs in its effort to eliminate inter-sc interference whereas DC strive to maintain both connections to the macro-cell and the femtocell, thus elCIC is mainly used in co-channel deployment to solve the MC to SC interference and DC is used for the dedicated or orthogonal carrier frequency deployment where the traffic flow splitting is an issue. The use of SCs for MTC connectivity rather than direct Macro-cells in the radio access network provide the benefit of stronger separation of MTC and H2H traffic, closed access as explained above as well as coverage extension where SCs provide local connectivity for MTC devices located in rural areas, indoors and other remote areas without network re-planning. Another vital issue for consideration is the use of machines belonging to non-3GPP networks in the HetNet, such as IEEE 802.11ah (Low Power Wi-Fi). This connection between Wi-Fi enabled devices and LTE-A MTC devices can be achieved for example through conventional Internet communication. An impending bottle neck of the use of small cell networking for M2M traffic evacuation is the backhauling, as stated in, linking each SC to the core network via fiber wired backbone is not efficient nor cost wise advisable particularly as the number of SC becomes significant. Among other suggestions, the mmWave MIMO or massive MIMO backhaul for SC technique was suggested.

5.3 Massive MIMO/HetNet

MTC devices (M2M communication) will be largely supported in Massive MIMO systems as compared to existing WLAN, GSM, LTE and LTE-Advanced wireless technologies. In order to accommodate the large increase of M2M in cellular networks without degrading the H2H communication, many 5G system architecture has been proposed including the use of MmWave Massive MIMO based wireless backhaul for small cell HetNet data traffic evacuation. Combining small cells densification (Heterogeneous networks) with massive MIMO as shown in Figure 5 where small cells aggregate the M2M traffic via Home evolved NodeBs (HeNBs) will allow a signifi-

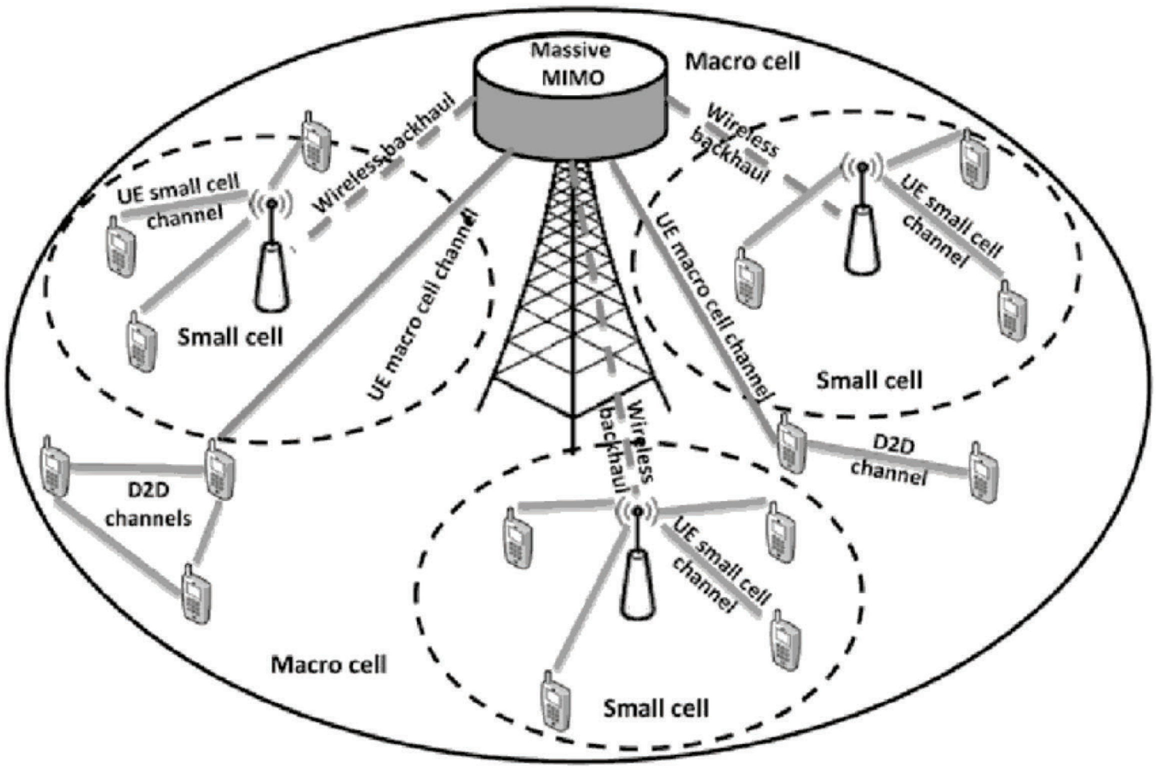

Figure 5. SCs Traffic Backhauling with Massive MIMO.

cant reduction in congestion and overloading of radio access and core networks.

According to network densification using small cells in a 5G network with massive MIMO and its Spatial Division Multiplexing and Transmit Beamforming[30,31] deployed at the macrocells is complementary and enhances each other's performance though it did not explain how this cooperation benefit the M2M and H2H traffic challenges in a cellular network. The use of HeNBs for M2M aggregation, instead of Macro-eNodeBs (MeNBs), in the radio access network was explained to achieve stronger separation of M2M traffic from H2H traffic signals, provide closed access as the HeNBs allows only those M2M devices/machines which belong to its Closed Subscriber Group (CSG) and finally it provide remote coverage for rural areas and cell edges.

6. Conclusion

We have looked at the three main cellular technologies for evacuating M2M communication in the IoT application and by extension for smart city as well. We have also considered the use of mmWave massive MIMO based backhauling for evacuating M2M traffic from small cells deployment which enables the separation of M2M traffic from H2H traffic thereby eliminating the congestion of the core network by the humongous M2M traffic thereby negatively affecting the H2H traffic. The massive MIMO antennas and millimeter wave communication technologies has enabled the deployment of 5G ultra-dense cellular networks in all cellular scenarios.

7. Aknowledgement

We acknowledge with thanks the Covenant University for the funding this work.

8. References

1. Stankovic AJ. Research Directions for the Internet of Things. IEEE Internet of Things Journal. 2014; 1(1):3-9. Crossref.
2. Jara JA, Ladid l, Skarmeta A. The Internet of Everything through IPv6: An Analysis of Challenges Solutions and Opportunities. Journal of Wireless Mobile Networks Ubiquitous Computting and Dependable Applications. 2013; 4(3):97-118.
3. Zanella A. Internet of Things for Smart Cities. IEEE Internet of Things Journal. 2014; 1(1):22-32. Crossref.
4. Andrusenko J, Burbank LJ, Ouyang F. Future Trends in Commercial Wireless Communications and Why They Matter to the Military. Johns Hopkins APL Technical Digest. 2015; 33(1):1-10.
5. Idowu-Bismark OB, Ibhaze EA, Atayero AA. Mimo Optimization Techniques and Their Application in Maximizing Throughput for 3GPP HSPA. Journal of Wireless Networking and Communications. 2017; 7(1):1-8.
6. Papadopoulos H, Wang C. Massive MIMO Technologies and Challenges towards 5G. IEICE Trans Communication. 2016; E99-B(3):602-21.
7. Cimmino A, Pecorella T. The Role of Small Cell Technology in Future Smart City Applications. Transactions on Emerging Telecommunications Technologies Trans. 2013; 25(1):11-20. Crossref.
8. Chen M, Wan J, Li F. Machine-to-Machine Communication: Architectures, Standards and Application. KSII Transactions on Internet and Information Systems. 2012; 6(2):480-97. Crossref.
9. Mehmood Y, Haider N. Impact of Massive MIMO Systems on Future M2M Communication. 2013; p. 534-7.
10. Cellular networks for massive IoT. Ericsson White paper. 2016; p. 1-13.
11. 4G Americas. Cellular Technologies Enabling the Internet of Things. 2015; p. 1-65.
12. Figueiredo FAP, Cardoso FACM. On the Application of Massive MU-MIMO in the Uplink of Machine Type Communication Systems. Brazil: Research and Development Center on Telecommunication. 2015; p. 1-7. Crossref.
13. Lee CH, Lee SH. Mobile Small Cells for Further Enhanced 5G Heterogeneous Networks. Information Telecommunication and Electronics. 2015; 37(5):856-66. Crossref.
14. Lu L, Li GY. An Overview of Massive MIMO: Benefits and Challenges. IEEE Journal of Selected Elected Topics in Signal Processing. 2014; 8(5):748-52. Crossref.
15. Tsai YH. Next generation Tech Trend for Global Critical Communication Standard. Institute for Information Industry. 2013.
16. Condoluci M, Dohler M, Araniti G, Molinaro A, Zheng K. Towards 5G Dense Nets: Architectural Advances for Effective Machine-Type Communications over Fem to cells. IEEE Communications Magazine. 2015; 53(|1):134-41.
17. Militano L, Araniti G. Device-to-Device Communications for 5G Internet of Things. EAI Endorsed Transactions on Internet of Things. 2015.
18. Narrowband IoT in the cloud Ericsson. Available from: www.ericsoon.com/research-blog/lte/narrowband-iot-cloud/. Date accessed: 01/09/2016.
19. Wang YPE, Lin X. A Primer on 3GPP Narrowband Internet of Things (NB-IoT). 2016; p 1-8.
20. Bhushan N, Li J, Malladi D. Network Densification: The Dominant Theme for Wireless Evolution into 5G. IEEE Communications Magazine. 2014; p. 1-8. Crossref.
21. Larsson EG, Edfors O, Tufvesson F, Marzetta LT. Massive MIMO for Next Generation Wireless Systems. 2014; 52(2):186-95.
22. Ergen SC. ZigBee/IEEE 802.15.4 Summary. 2004; p. 1-37.
23. Rusek F, Persson D. Scaling up MIMO: Opportunities and Challenges with Very Large Arrays. IEEE Signal Processing Magazine. 2013; 30(1):40-60. Crossref.
24. Larsson EG, Edfors O. LUND University: MASSIVE MIMO for next generation wireless systems. 2014; p. 1-21.
25. Harmonizing the industry on a narrowband IoT (NB-IoT) specification. Available from: Crossref. Date accessed: 29/09/2015.
26. Palattella MR, Dohler M. Internet of Things in the 5G Era: Enablers, Architecture, and Business Models. IEEE Journal on Selected Areas in Communications. 2016; 34(3):510-27. Crossref.
27. Zheng K, Ou S, Yin X. Massive MIMO Channel Models: A Survey. Hindawi Publishing Corporation: International Journal of Antennas and Propagation. 2014; p. 10.
28. Hoydis J. Massive MIMO Systems with Non-Ideal Hardware: Energy Efficiency, Estimation, and Capacity Limits. IEEE Transactions on Information Theory. 2014; 60(11):7112-39. Crossref.
29. Perez DL, Ding M. Towards 1G bps /UE in Cellular Systems: Understanding Ultra-Dense Small Cell Deployments. IEEE Communication Surveys and Tutorials. 2015; 17(4):2078-101. Crossref.
30. Araujo DC, Maksymyuk T. Massive-MIMO: Survey and future research. 2016; 10(15):1938-46.
31. Agboje EO, Idowu-Bismark OB, Ibhaze EA. Comparative Analysis of Fast Fourier Transform and Discrete Wavelet Transform Based MIMO-OFDM. International Journal of Communication Antenna and Propagation. 2017; 7(2):168-75. Crossref.