A Review on Vertical Handover Techniques applied in Heterogeneous Cellular Networks

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***Abstract*—Global mobile data traffic reached 11.5 exabyte per month at the end of 2017, up from 6.7 exabyte per month at the end of 2016. Therefore to keep-up with this ever-increasing data demand, Heterogeneous network seams to be the most appropriate resolution. A Heterogeneous network consists of a combination of different types of nodes (small-cells and macro-cells) that share coverage regions and may use different radio access technologies. Whenever a user in active connection moves from one cell to the other, the network must transfer the connection to a new cell to maintain the communication service in a process called handover. However this handover process must be seamless. Some key handover challenges and design issues for the next generation of wireless networks was discussed in this review.**

***Index Terms*—Heterogeneous network, vertical handover, network selection, mobility models**

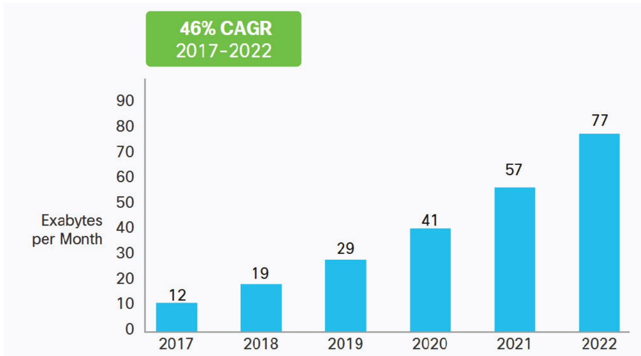

Fig. 1. Mobile data traffic projection from 2017 to 2022 [2]

I. Introduction

The demand for data and the number of smart phone users worldwide today is rapidly increasing. The number of mobile broadband subscriptions is growing globally at about 25% each year, and it is predicted to reach 7.7 billion by 2021 [1]. According to cisco VNI Global Mobile data traffic forecast (Figure 1), by the year 2022, the monthly global mobile data traffic will be 77 exabyte and the annual traffic will reach almost one zettabyte (10^{21}). Global mobile data traffic reached 11.5 exabyte per month at the end of 2017, up from 6.7 exabyte per month at the end of 2016 (one exabyte is equivalent to one billion gigabytes, and one thousand petabytes) [2]. Therefore to keep-up with this ever-increasing data demand, Heterogeneous network seams to be the most appropriate resolution.

A combination of various technologies will be employed to cater for the different services is needed by mobile users in Next generation networks. These different RATs have different capabilities such as different supported data rates, cell coverage area, cost, etc [3]. For example, UMTS provides high coverage area, high cost and low data rate from 144 Kbps to 2 Mbps at 10 Km/h to maximum 500 Km/h depending on propagation channel, while the Wi-Fi provides low coverage area, low cost and high data rate from 1 Mbps to 54 Mbps at 30 m to maximum 450 m [4]. UMTS and Wi-Fi have characteristics that complement one another. WLAN provides high data rates at a relatively lower cost but with limited coverage area while UMTS is known to provide a wider coverage area, full mobility and roaming but offers low bandwidth connectivity for traffic. No one Network access can solely provide low latency, low power consumption and high bandwidth to a large number of users thus integration of various access technologies can help achieve higher desired service capabilities. The fifth generation (5G) of mobile communication is expected to intergrate different radio access network (RAN) as well as base station of difference power level.

II. Overview of Heterogeneous networks

A Heterogeneous cellular network consists of a combination of different types of nodes (small-cells and macro-cells) that share coverage regions and may use different radio access technologies as shown in Figure 2. The small-cells (micro-cells, pico-cells, femto-cells or relays) provide high data rate access to users located indoors, but also provide coverage and seamless communication to low-mobility outdoor users [5].

A **macro** cell base station delivers the best performance and coverage, but is very expensive to roll out. The cell radius of a macro base station is around 130 km and can handle more than 256 users [6]. The average transmitted power is more than 10 W; peak power is more than 100W. A macro base station consists of one or more reasonable-sized cabinets plus a big tower, which means that in very populated areas acquiring a site to install the macro base station might be difficult and very expensive.

Microcell is designed to cover only a limited area, the micro cell antenna is usually placed below the roof level of surround-

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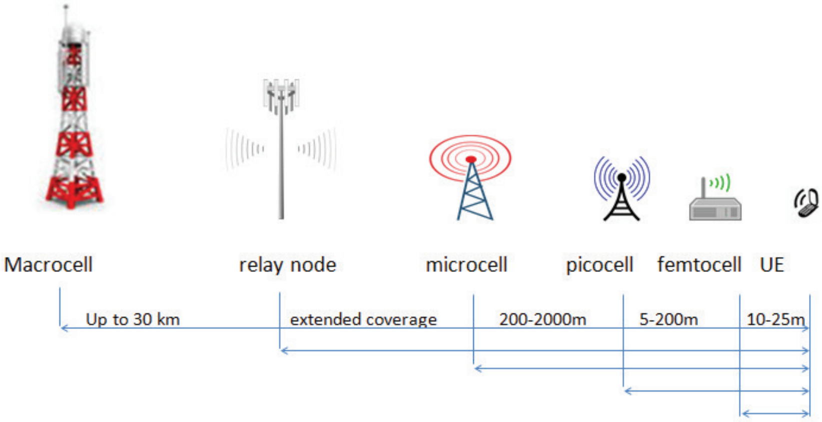

Fig. 2. Heterogeneous network base station [11]

ing buildings [7]. Due to their small size, micro cells have the potential to offer an extremely high system capacity. It would, however, be costly to provide sufficient coverage within an area using only micro cells, and the operator may therefore need a combination of macro and micro cells.

Picocells are mainly used to extend the coverage in dead zones so as to support more users, they have lower transmission power compared to macrocells and microcells. Picocell BTS could be used either indoor or outdoor, the cell radius roughly 200 meters.

Femtocells is a low-power cellular base station principally designed for delivering better in-building coverage in residential and small business offices [8]. It is cost-effective as because it can be connected to the existing operators network via broadband like DSL, or Cable, without the need for expensive towers. A call that is initiated from a hand set equipped with femtocell base station would start at cell phone then sent to the femtocell, which would then go from femtocell to internet via broadband connection and end up at cellular network.

III. Handover

As the size of cells decreases, the number of cells will increase, providing service to more users. Whenever a user in active connection moves from one cell to the other, the network must transfer the connection to a new cell to maintain the communication service in a process called handover. There are cases of poor quality of service (QoS) experienced by users as well as active calls that get dropped; all these can be attributed to delayed handover (HO) or outright case of an unsuccessful handover process [9]. The handover process is either executed by the network or by the user equipment and the process has to be seamless. Two possible errors that may occur during a handover process are the handover failure and the Ping-Pong handover [23]. The handover failure occurs if, during the handover procedure, the signal-to-interference-plus-noise ratio (SINR) falls below the required threshold to maintain the communication link. On the other hand, the Ping-Pong handover is produced if a user connects to a neighbour cell and shortly completes a second handover back to its former source cell. While handover failures interrupt the communication link, Ping-Pong handovers are considered unnecessary.

However, there are different types of handover; hard and soft handover. In hard handover, there is a break in the connection while switching from one cell to another. The radio links from the mobile station to the existing cell is broken before establishing a link with the next cell. It is generally an inter-frequency handoff. In soft handover on the other hand, at least one of the links is sustained when radio links are added and removed to the mobile station. This ensures that during the handoff, no break occurs. This is generally adopted in co-located sites. It is a make before break policy. A soft handover occurs when the mobile station is in the overlapping coverage area of two adjacent cells. Soft handover can be further classified into Horizontal and vertical handover. In horizontal handover, the MN (mobile node) performs a handover between the APs (access point) or BSs (base station) of the same network. This type of handover requires less handover delay compared to the other types of handover. While in vertical handover, the MN performs handover from one AP or BS to another AP or BS of a different network. In the case of vertical handover, the route to the destination remains the same, and only the interface is changed [20].

In November 2008, the Institute of Electronics and Electrical Engineering (IEEE) published a new standard called IEEE 802.21: media independent handover (MIH) standard. A framework that enables seamless handover between heterogeneous technologies. This framework is based on a protocol stack implemented in all the devices involved in the handover. The defined protocol stack aim to provide the necessary interactions among devices for optimizing handover decisions [13]. Some of the goals of IEEE 802.21 include:

- A framework that enables seamless handover between

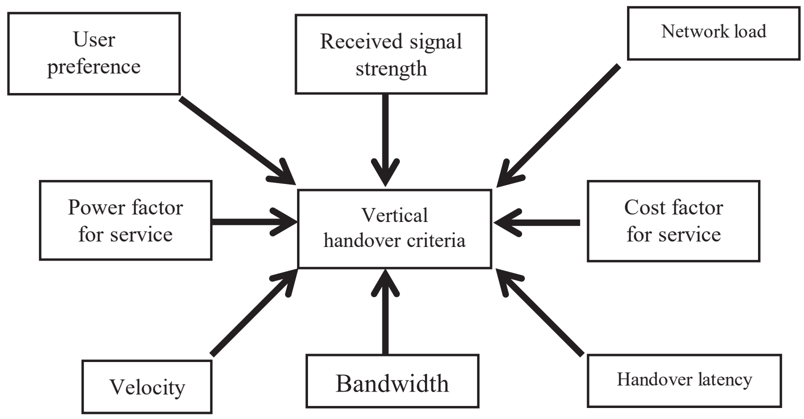

Fig. 3. Vertical handover criteria

heterogeneous technologies. This framework is based on a protocol stack implemented in all the devices involved in the handover. The defined protocol stack aims to provide the necessary interactions among devices for optimizing handover decisions.

- The definition of a new link layer SAP that offers a common interface for link layer functions and is independent of the technology specifics. For each of the technologies considered in 802.21, this SAP is mapped to the corresponding technology-specific primitives. The standard draft includes some of these mappings.
- The definition of a set of handover enabling functions that provide the upper layers (e.g., mobility management protocols such as Mobile IP), with the required functionality to perform enhanced handovers. These functions trigger, via the 802.21 framework, the Corresponding local or remote link layer primitives defined above.

A. *Criteria for Vertical Handover*

In heterogeneous cellular network, it is crucial to design an efficient vertical handover algorithm to maintain an "always best connected (ABC)" system. Several approaches have been proposed for solving the problem of vertical handover. Traditional handover decision schemes are based mainly on the selection of network on the basis of a single parameter. However, the requirement of one user is becoming widely different from another, this makes single parameter inadequate for making handover decision. Researchers have therefore recommended different scheme based on multiple criteria such as delay, jitter, bit error rate (BER), bandwidth etc as shown in Figure 3. These criteria or metrics are measurable qualities that suggest if handover initiation is needed or not. These criteria are described as follows:

- Network related: received signal strength (RSS), bit error rate (BER), cost, bandwidth, link quality etc.
- Mobile terminal-related: velocity, location information, battery power etc.
- User related: user profile and preference.

Some of these criteria are briefly explained below:
Received signal strength: This is one of the critical and mostly used criterions in vertical handover decision making. It represents the power of a received signal on a device. It is easy to measure and has a close relationship with link quality.
Cost factor for service: This can affect users' decision for network selections in heterogeneous network environment, as charging policy (encompassing both traffic cost and roaming cost among diverse network) can significantly vary for different service providers.
Handover latency: For user equipment, it is described in terms of time duration or interval has elapsed between the arrival of the first packet along the new access router. Handover latency plays crucial role in the interactive cellular application, as it could vary among different technologies.
Bandwidth: Bandwidth is a measurement indicating the maximum capacity of a wired or wireless communication link that transmits data over a network connection in a given amount of time.
Velocity: Is the average speed of the user equipment. This is a very important criterion in vertical handover decision.
User preference: A specific access network can result in selection of one sort of network over the other candidate network.
Table 1. shows a comparison of various handover methods classified based on four categories.

IV. Modelling approaches for User Mobility

Mobility model is designed to describe the movement pattern of mobile users, and how their location, velocity and acceleration changes over time. Since mobility patterns may play a significant role in determining the protocol performance, it is desirable for mobility models to emulate the movement pattern of targeted real life applications in a reasonable way [10, 14]. Mobility model is an invaluable tool for network planning and design. They are useful in areas such as network architecture comparison, network resource allocation and performance evaluation of protocols [15]. Some common approach to modeling human movement includes;

TABLE I
COMPARISON OF VARIOUS HANDOVER METHODS

Category of handover	Existing vertical handover decision method	Advantages	Disadvantages
Single Criteria	Rss-based method	Simple algorithm	Increases rate of handover Increase ping-pong effect
	Bandwidth-based method	Good network selection Good throughput performance	Inefficient bandwidth computation
	Cost function	Reduced ping-pong effect Call drop probability reduces	Increased system overload
Multiple criteria	Context-aware method	Call drop probability reduces even more	Complex algorithm
	Media-independent handover	Good network selection Reduced latency	Increased consumption of resources High signalling overhead
	MAND (multiple-attribute decision-making)	Better decision due to multiple criteria	Performance is dependent on traffic class
Computation	(NNs) Neural Networks	Reduced handover delay	Centralized control More complex algorithm
	(FL) Fuzzy logic	Reduced handover delay	More complex algorithm More processing time
Multi-criteria and computation	MAND AI	Precise data for handover Reduced handover decision delay	Terminal-based decision Huge training process
	MAND context-aware	Improved QoS for users	Terminal based decision Unreliable handover decision at high speed

Fluid Model: In fluid model, traffic flow in conceptualized as the flow of a fluid. It describes microscopic movement behavior. One of the simplest fluid model describe the amount of traffic flowing out of a region to be proportional to the population density within the region, the average velocity and the length of the region boundary.

Markovian Model: This describes the individual subscriber movement. In this model, a subscriber will either remain in a region or move to an adjacent region according to a transition probability distribution. One of the limitations of this approach is that there is no concept of trips or consecutive movement through a series of region.

Gravity Model: Gravity model has been used to model human movement behavior in transportation research. They have been applied to regions of varying sizes from city model to national and international model [16].

In mobile environment, all users should concurrently get full mobility while preserving the QoS where users mobility significantly affects the QoS. Mobile Station must update the Base Station they are to be connected during its user movement [17]. Predicting the next wireless network (station) with the best QoS, could be used in solving the problems of handover delay and redundant handover. Another benefit of handover prediction is to reduce the interruption in hard handover as well as in the situation of soft handover. When a proper prediction is achieved, redundant handover numbers and unnecessary handovers are minimized. Handover prediction helps the MS in accepting the next station to transfer the data connection [18]. Mobile network prediction schemes are very important in mobile communication and is said to be successful when it is able to implement a smooth handover process and keeps unbroken connection.

V. DISCUSSION OF PAST RESEARCH

In [21], the decision to trigger the handover procedure is based on the data rate required by the applications running on the mobile device during the handover. According to the reported results, a reduction in the performed handover rate and a throughput increase was achieved. The authors in [9] initiates an enhanced network selection and vertical handover scheme that is context aware and based on the user preference utilizing grey relational analysis (GRA) integrated with particle swarm optimization (PSO) to provide continuous connection in terms of throughput and delay. In [12], a novel handover method was proposed named EHoLM: Enhanced handover for low and moderate speed UEs of LTE-A and beyond heterogeneous cellular network which reduced the handover failure rate thus improved the network performance as well as the user experience.

In [13], a performance evaluation of vertical handover in Heterogeneous Network based on SINR is presented and compared to a vertical handover based on the received signal strength (RSS). The results indicate that the SINR-based vertical handover produces a higher system throughput and lower end-to-end delay in comparison to an RSS-based vertical handover. A trade-off between unnecessary handovers and handover failures in Heterogeneous Network is confirmed in [19]. In this work, the authors proposed a method of reducing unnecessary handover by mobile users travelling at high-speed between micro-cells to form a list of candidate small-cell for the handover by estimating the time of stay of a user in small-cells to form a list of candidate small-cells for the handover. Only small-cells whose time of stay is estimated to be longer than a minimum time are included in the list. Therefore, handovers to small-cells whose time of stay is predicted to be too short are avoided.

The authors in [22] proposed a method that simultaneously reduces the percentage of handover failure and Ping-Pong handover by attempt to delay the handover as much as possible without producing a handover failure, which in turn reduces the likelihood of Ping-Pong handover. The authors in [24] analyzed vertical handover in heterogeneous network with randomly deployed small cell of limited range by modeling network and user mobility as geometric elements and the statistics on vertical handover were analyzed by geometric probability. From the analysis, it was established that the number of vertical handovers is a function of the small cells, the size of the small cells and UE mobility model. The authors in [25] proposed a vertical handover algorithm based on neural network frame. He introduced the BP (backward propagation) neural network to participate in the construction and execution of this algorithm also introduces the 5G network in an environment where UMTS, GPRS, WLAN and 4G network coexist using moving speed, maximum transmission rate, minimum transmission delay, signal-to-interference plus noise ratio, bit error rate and packet loss as input criteria of the neural network and network download rate as a key factor to determine the performance of the network.

VI. Future Research

As the demand for data continues to grow globally and drive advancement in cellular technology, the number of base stations will continue to increase and the challenge of efficient handover processes will intensify. Consequently, improved models and algorithms are required that make intelligent decisions for handover based on the relevant criteria and depending on the network scenarios. Mobility models will continue to play a huge role in understanding the network patterns and enhancing handover. In our current work, we are developing a user mobility model and exploring prediction of user movements into base station coverage areas. These will form the basis for developing a more robuts vertical handover algorithm.

VII. Conclusion

This paper presents a brief review on the Vertical Handover (VH) algorithms. Vertical handover in heterogeneous cellular network provides users with seamless roaming among different networks selecting the suitable network that satisfies their QoS requests. The review is based on the categories of network available in a heterogeneous cellular network and criteria that are considered as crucially important parameters in VH handover process. we also discussed how network prediction can affect the QoS of a network. Moreover, the advantages and drawbacks of the recent works have been discussed. Also, some key handover challenges and design issues for the next generation of wireless networks have been studied.

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