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Mobility Management in Integrated Macrocell Femtocell Network- A Survey

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Abstract— Femtocell is low power, low cost, short range indoor base station. Support of femtocell is an integral part of latest wireless communication technologies to achieve high capacity demand & high data rate. For successful deployment of femtocell, Smooth integration of femtocell network in macrocell network and seamless communication between macrocell & femtocell network is very important. Conventional handoff algorithms used in macrocell need some modifications to well satisfy handover management in integrated macrocell femtocell network. In this survey article, various existing handover decision algorithms for the integrated macrocell-femtocell network are discussed.

Keywords — Femtocell, Macrocell, CAC, Handover management, UE, UMTS, FAP-PF, Proximity Check

I. INTRODUCTION

Capacity demands of modern mobile telecommunication networks are increasing year by year. Now days, it's a smart phone era. As per International Telecommunication Union research, smartphone users are consuming five times more data capacity on average than standard mobile phone users. Smartphone penetration is growing 30% per annum and capacity demand increased by 70-200% per year. Current traditional cellular network is already suffering with network capacity crisis so it is obvious that it can't cope up with this data explosion. Due to lack of resource availability, current wireless technologies are not able to use advance application in effective manner & lot of issues left unsolved in this area.

This rapid increase in mobile data activity has attracted various researchers and increased the requirement on developing new innovative technologies and cellular topologies which can meet these huge demands in energy and cost efficient manner [1]. Some studies on wireless usage show that more than 50% voice calls and more than 70% data traffic are originated indoor. If we offload this indoor traffic then it will be great relief to service operator. From the wireless operator point of view, the ability to offload a large amount of traffic from macro cellular networks to femto cellular networks is the most important advantage of the femtocell macrocell integrated network architecture. This will reduce the investment capital, maintenance cost, and the operational costs. Other than this, it will also improve the reliability of the cellular networks [2].

Femtocell network provides higher data rate and reliability for subscribers & reduced amount of traffic on expensive macrocell network. Femtocells are a cheap and fast way to offer capacity and coverage to homes and offices. They are home BS (Base Station) which combines the internet access technologies like DSL (Digital Subscription Line) and cable with mobile technologies to improve customer satisfaction & operator revenue. Efficient handling of handover calls is an important aspect of successful femtocell and macrocell integration [3]. Traditional handoff algorithms used in macrocell can't satisfy the mobility of users in hierarchical macro/femto cell network efficiently [4]. Various handoff algorithms used in conventional macrocell network take handover decision with respect to RSSI & this approach is not enough for femtocell network.

In this Paper, We will discuss other aspects used for handover decision proposed by various authors. Section 2 gives integrated macrocell femtocell network architecture. This section talks about network elements & key entities which take care of communication between femtocell & macrocell. Section 3 takes us through key aspects & phases of handover decision/execution in femtocell. Section 4 has survey of various handover decision algorithms & finally this paper concludes with pros & cons of proposed algorithm.

II. FEMTOCELL NETWORK ARCHITECTURE

Connecting femtocells to operator cellular networks requires unique architectures which can address the security needs of operators and mobile users and also support the deployment of scalable femtocell networks that can serve millions of subscribers. The femtocell network architecture is also designed to allow ordinary consumers to install femtocells with plug-and-play simplicity. Zero-touch service activation by the user is also supported by significant adaptive and self-organizing capabilities built into this architecture. Network architecture is also critical in supporting emergency calling services, which can be delivered to mobile devices inside buildings with the same accuracy and reliability as fixed-line emergency calling [5].

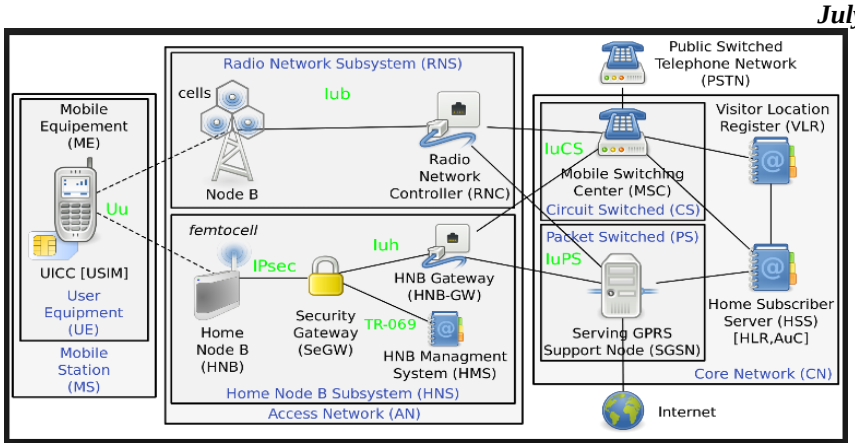

Fig.1: Integrated UMTS macrocell & femtocell Architecture

As shown in fig 1. Femtocell access point, security gateway & Femtocell device management system are key network elements of femtocell network architecture.

Femtocell Access point is primary node of femtocell network. It performs base station & base station controller activities similar to our traditional cellular networks and connects to the operator network via the Internet. Security gateway is network node, which takes care of secure Internet connection between femtocell users and the mobile operator core network. Femtocell device management system located in operator network and takes care of provisioning, activation and operational management of femtocells using industry standards such as TR-069. It manages all online communication devices & Ensures scalability.

Other than these three network elements femtocell networks uses below two entities to enable communication between femtocell & macrocell.

- Femtocell Convergence Server (FCS), Femtocell Network Gateway (FNG) for circuit switched calls
- Packet data serving node PDSN or xGSN for packet calls

Femtocell network support 3 access modes:

1) *Close access Mode*: Access provided to only close subscriber group. The CSG manager shall be able to add, remove and view CSG membership. Inefficient use of spectrum reserved for CSG in case there are very less CSG Members.
2) *Open Access Mode*: Access provided to all. It's simple & no additional configuration is needed. Limiting factors are the capacity of the FAP and the capacity of the backhaul connection.
3) *Hybrid Access Mode*: It is combination of close & open mode. Few resources are reserved for CSG user & rest can be accessed by all.

III. HANDOVER PROCEDURE AND SCENARIOS

Seamless mobility across macrocell & femtocell is complicated to implement as femtocells are randomly deployed over macrocell network and number of femtocells can be in hundreds under one macrocell coverage area. We have Hand-in (macrocell to femtocell HO), Hand-off procedure (femtocell to macrocell HO) and Inter-FAP (in-between two femtocells HO) handover scenarios in femtocell. Out of these scenarios, Hand-in scenario is quite demanding and a difficult one as there are huge numbers of possible targets femtocell access points and UE needs to select best candidate. Currently researchers talk more about handover between macrocell to femtocell or vice versa. Various approaches presented in this paper are focused on hand-in scenario. The handover procedure is mainly divided into three phases: handover information gathering phase, handover decision, and handover execution phase.

1. Handover Information Gathering:

This phase of Handoff collects all contextual information, access modes of femtocell through monitoring and measurements. After collecting all information, neighbour list is prepared for handover.

2. Handover Decision Policies:

This phase defines the handover decision metrics as per system requirements or thresholds defined in network & accordingly select best candidate to handover the ongoing call.

3. Handover Execution:

This phase includes actual IP connectivity through the target access femtocell. HO execution consists of all necessary signalling procedures in the connected state.

IV. SURVEY OF HANDOVER DECISION ALGORITHMS FOR FEMTOCELL

This section summarizes the main HO decision criteria in the current literature. As mention in section three this literature survey is mainly focused on hand-in handover scenario. Algorithms discussed in this section talks about the

criteria's checked before handing over that call to femtocell or keeping it with macrocell. Various HO algorithms proposed are classified based on:

A. RSSI and Wireless transmission loss
B. UE movement pattern
C. UE Speed
D. Traffic Type
E. Received signal strength & Quality
F. Self-organising network concept
G. Prefetch based or Proximity check

A. Handover decision algorithm based on RSSI and Wireless Transmission Loss (RTWL- HO)

Peng Xu, Xuming Fang, Rong He, Zheng Xiang [6] proposed an efficient handoff algo based on wireless transmission loss & received signal strength. This algorithm considers asymmetry of transmit power of macrocell & femtocell, and can be applied to hierarchical network immediately. Since transmit power of macrocell BS is more than femtocell BS, received signal strength level is also more for macrocell. With conventional handover approach, number of handovers are more in macrocell network & femtocell network is less utilized hence this algo considers wireless transmission loss with RSS for HO decision.

The RTWL-HO algorithm can be described in below pseudo codes:

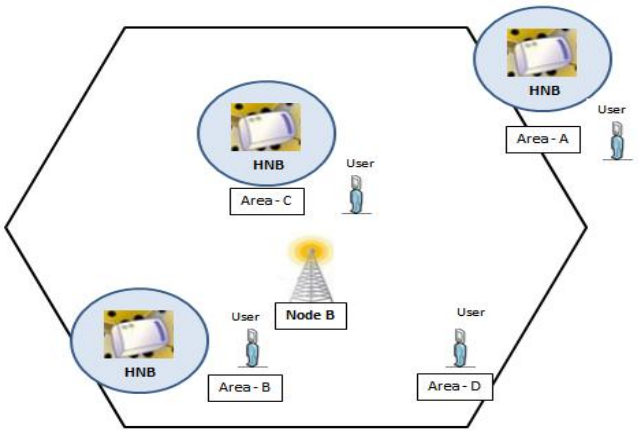

Fig.2: RTWL-HO by Pang Cu, Fuming Fang, Rung He, Sheng Xiang

If *So > Sf, th*
If *Sf > Sm+H*, handover to the HNB (FBS) --- (Area-A)
else
if *Wc, m >Wc, f*, handover to HNB (FBS) --- (Area-B)
else keep it associated to Node B (MBS) --- (Area-C)
Else keep it associated to Node B (MBS) --- (Area-D)
Where,
MBS= Macrocell base station = Node B
FBS= Femtocell base station
HNB= Home Node B
Sf = Received signal strength level of femtocell
Sm= Received signal strength level of macrocell
Sf, th = Threshold RSS of femtocell = Minimum RSS level of femtocell in dBm
Sm, th= Threshold RSS of macrocell=Minimum RSS level of macrocell
H = hysteresis in dBm- time-based dependence of system o/p on current & past input
Wc, m = Wireless transmission loss of macrocell
Wc, f = Wireless transmission loss of femtocell
Area A: HNB is far away from Node B, and MS will handoff to femtocell
Area B: HNB is deployed close to Node B, and the Received Signal Strength is incomparable because of large asymmetry in transmitter power.
Area C: HNB is deployed close to Node B, and the Received Signal Strength is incomparable because of large asymmetry in transmitter power.
Area D: MS is almost not in coverage of HNB.
This algorithms increases utilization of femtocell network but it might delay handover procedure.

B. Handover decision algorithm based on UE movement pattern

Due to small coverage area of femtocell numbers of handovers are more in femtocell network which again increases signaling load & cost.

Tom Priebe [7] suggested HO scheme based on user mobility & movement pattern. Based on time UE connected to femtocell & velocity of UE, user moving pattern can be predicted by a server & declare user as "temporary femtocell visitor". This algorithm's design requires a central server for calculating the movement patterns of cell phone users and a huge privacy problem, as this server is not just calculating of user movement pattern with but also storing the subscriber's movement data.

Nak Woon Sung, Ngoc-Thai Pham, Thong Huynh, and Won-Joo Hwang [8] also proposed "prediction association control" algorithm which predicts user movement using markov chain model & decides next target BS for handover. Design of central server issue is resolved in this algo. By reducing frequent handovers of mobile stations, it helps to improve throughput but markov chain process increases complexity & computational time of system.

C. Handover decision algorithm based on UE Speed

Mostafa Zaman Chowdhury & Yeong Min Jang [9] talks about reducing unnecessary HO based on UE Speed, velocity and angle of movement. Detected RSS of target BS, user speed & Carrier to interference ratio (CIR) is compared with predefined thresholds for handover decisions. If it is satisfy HO criteria then HO execution takes place else call will remain in macrocell. This algorithm does not consider Transmission power difference between femtocell and macrocell. Fig. 3 shows the flowchart of this algorithm

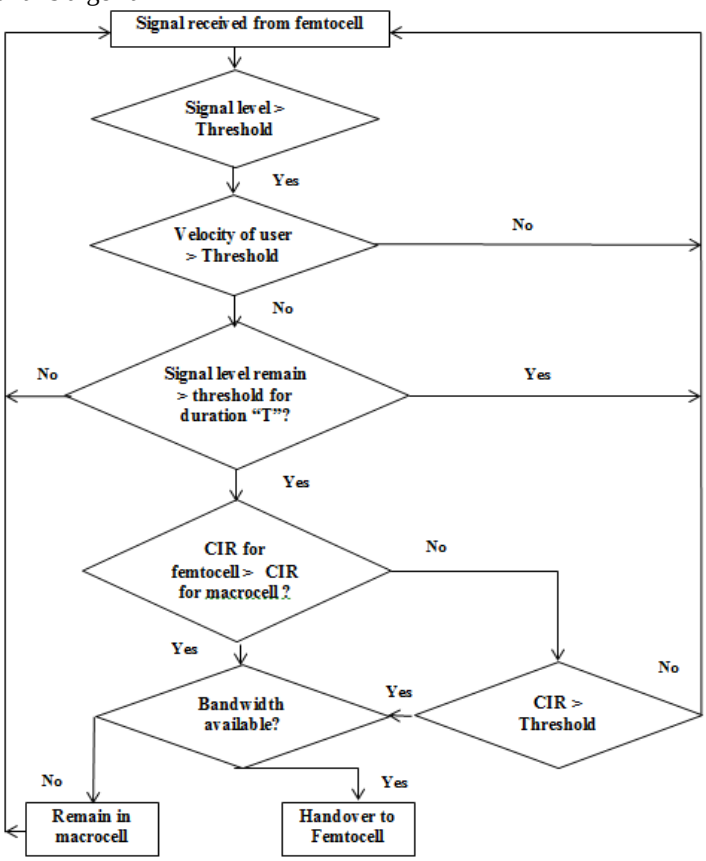

Fig.3: UE Speed based HO by Mostafa Zaman Chowdhury & Yeong Min Jang

Few more authors considered this approach for reducing signalling load & cost. Aicha Salem & K. Sethom [10] suggested a novel velocity based handoff decision policy for LTE femtocell network. This Scheme based on vehicle speed, interference, crossing time and handover latency for HO. This paper defines HO decision metrics (B) as below.

$B = \alpha \times (Cc - \lambda) \times (\Delta T - L) + (1-\alpha) \times Cs * \Delta T$

Where,

$$\alpha = \begin{cases} 0 \text{ When HO is not executed} \\ 1 \text{ When HO is executed} \end{cases}$$

ΔT = *Cell residential time*

Cc = *Carrier Capacity*

L = *HO latency time*

Mostafa Zaman Chowdhury, Yeong Min Jang, and Zygmunt J. [11] used this user mobility approach to achieve network evolution and quality of service (QoS) provisioning for integrated femtocell and macrocell networks.

In 2011, Haijun Zhang, Wenmin Ma, Wei Li, Wei Zheng, Xiangming Wen and Chunxiao Jiang [12] suggested Low-complexity Handover Optimization Algorithm using user mobility concept. In this algorithm, when User mobility speed is more than pre-defined threshold then HO blocked to femtocell & call remain in macrocell network.

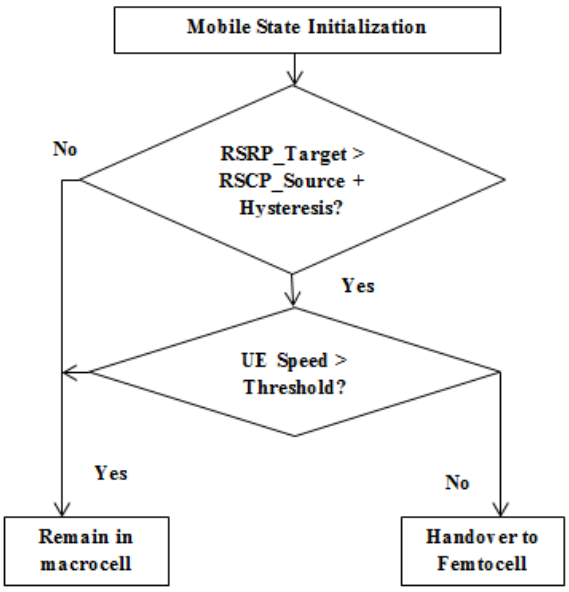

Fig.4: UE Speed & RSRP based HO by Haijun Zhang, Wenmin Ma, Wei Li, Wei Zheng, Xiangming Wen and Chunxiao Jiang

D. Handover decision algorithm based on traffic type

Wireless multimedia services are classified below three categories

1. Conventional class: Real time traffic such as VoIP
2. Streaming class: Another kind of real time traffic such as online video
3. Best effort class: Non- Real time traffic such as email

Dropping an ongoing service is more undesirable so more priority is given to real time traffic. Best effort class is non-real time traffic so it can afford to wait.

Ardian Ulvan, Robert Bestak and Melvi Ulvan[13] proposed Proactive & reactive algorithms for real time traffic & non real time traffic HO respectively.

a) Proactive Handover

In the proactive handover strategy, the handover can takes place any time before the level RSSI of current BS reaches the hysteresis threshold of handover [13]. This algorithm based on prediction of prediction of target femtocell access point and user movement and triggers the handover before handover hysteresis threshold (HHT). The probability of UE transition from one cell to another is modelled as a Markov process.

b) Reactive Handover

Due to small coverage area & high dense femtocell network, UE face very frequent and unnecessary handover as UE move from one FAP to other FAP repeatedly. UE speed based approach is used in reactive HO to mitigate the overhead of handover. The handover is triggered only when UE (almost) loses its serving cell signal.

The pseudo code of traffic based optimization algorithm can be seen below:

1. MOBILE STATE INITIALISATION
2. EXAMINE SPEED OF UE (V)
3. IF V > 10 Km/h
NO MACROCELL TO FEMTOCELL HANDOVER
4. ELSE IF V> 5 Km/h
PERFORM MOBILITY PREDICTION
IF Traffic = Real-Time Traffic
PERFORM PROACTIVE HANDOVER
ELSE IF Traffic = Non Real-Time Traffic
PERFORM REACTIVE HANDOVER
5. ELSE IF Traffic =Real-Time Traffic
PERFORM PROACTIVE HANDOVER
IF Traffic = Non Real-Time Traffic
PERFORM REACTIVE HANDOVER
6. ELSE
PERFORM NORMAL HANDOVER
RETURN

This algorithm support different type of traffic but Prediction of user mobility is quite difficult so error probability is more.

E. Handover decision algorithm based on Received signal strength & Quality

Hetal Surti and Krtan Goswami [14] proposed dual threshold method for HO to reduce unnecessary HO. In this algorithm we consider two different thresholds T1 & T2 for Macrocell & femtocell minimum required signal level respectively. Minimum threshold decided for femtocell is more than macrocell (T2>T1). By using the received signal quality measurements provided by the UE, this algorithm accounts for the impact of the interference [14]. When received signal strength of macrocell is less than T1 or when Ec/Io of macrocell is less that Ec/Io of femtocell then HO is given to femtocell conditionally femtocell need to maintain required signal strength for at least handover execution time.
The proposed algorithm is presented as below:

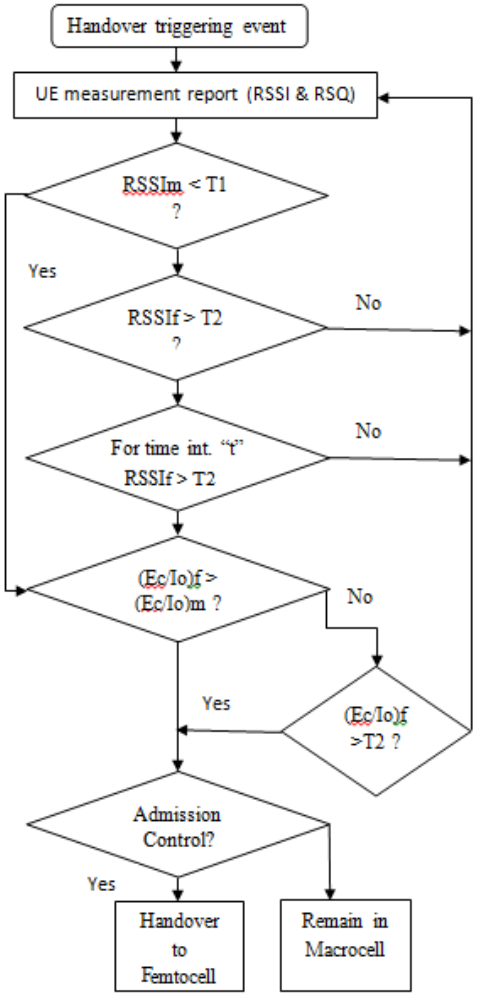

Fig.5: RSSI & Ec/Io based HO by Hetal Surti and Ketan Goswami

F. Handover decision algorithm using SON concept

As we know, femtocell is self-configured, self-optimised & self-healing unit. Femtocell, Macrocell BS & macrocell core network forms self-organising network. This SON concept is used in HO algorithm by Tijane Fatima Zohra Badri, Rachid Saadan, Samir Mbarki & Mohammed Wahbi. These authors proposed two algorithms: One using F-PF (femtocell policy function) for correcting neighbour list prepared by UE to reduce scanning time [15] & second uses SON location detection feature to add appropriate neighbour list [16]. These two algorithms help to prepare appropriate neighbour list for HO & HO decision taken accordingly.

Above described HO management algorithm using SON location detection feature is also discussed in "Handover management in high-dense femtocellular networks" by Mostafa Zaman Chowdhury and Yeong Min Jang [17].

These HO algorithms are self-optimized algorithms but HO decision based on SON concept only support higher wireless technologies.

a) HO using SON Femtocell policy function

Handover management scheme in LTE femtocell network article by Tijane Fatima Zohra Badri, Rachid Saadan, Samir Mbarki & Mohammed Wahbi [15] introduces F-PF entity which can interact with the femtocell and get the femtocell special information such as access mode of femtocell, CSG users etc. When the F-PF receives the handover requests containing the measurement parameters and neighbouring femtocell list which can accept HO, it obtains those femtocell CSG IDs, access mode, and current load. Then, it will contrast them with the allowed CSG list of the UE & modify neighbour list. After this HO decision & execution steps takes place. Proposed paper also discussed analytical model of algorithm to derive signalling cost.
Fig 6 represents flowchart of this algorithm:

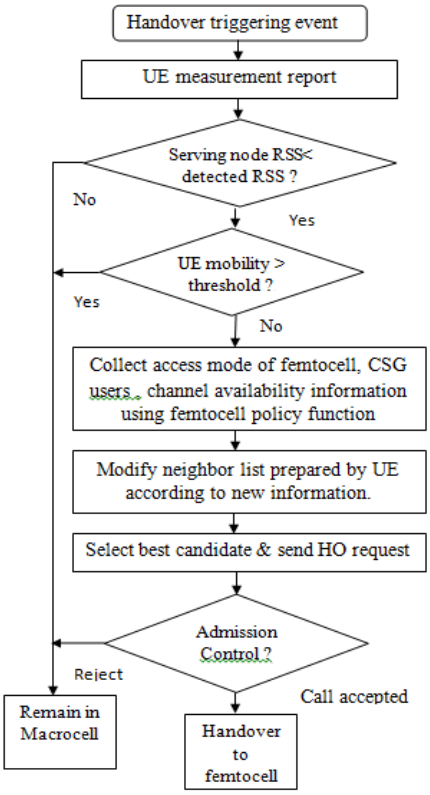

Fig.6: HO algorithm using femtocell policy function

b) HO using SON location detection feature

This concept is discussed in two research papers, one is by Mostafa Zaman Chowdhury and Yeong Min Jang [17] in 2013 & second paper is by Rachid Saadan, Samir Mbarki & Mohammed Wahbi [16] in 2015.

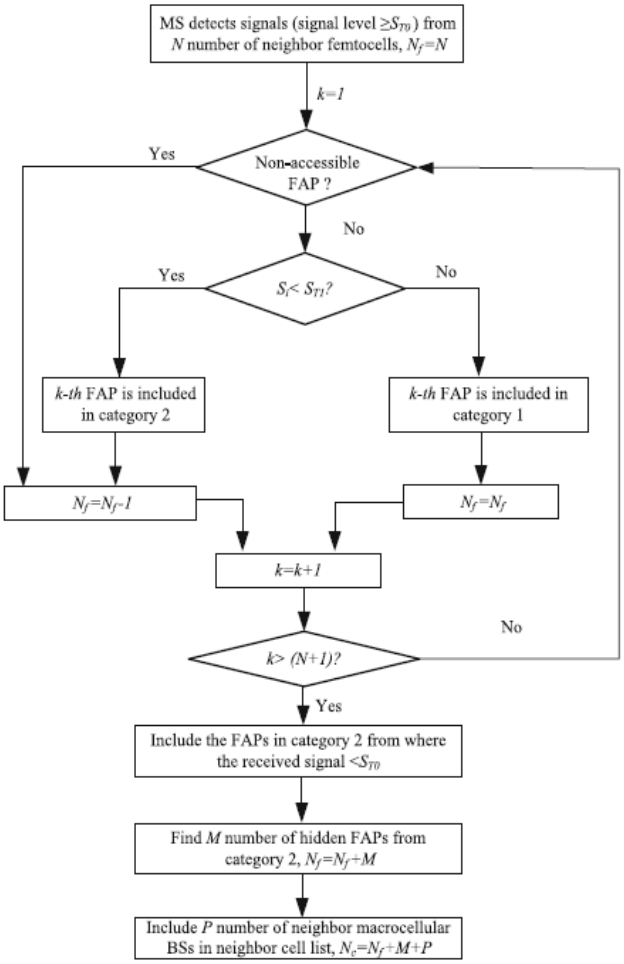

Fig.7: HO algorithm using SON location detection feature

Fig 7 shows flowchart of Novel Scheme for Neighbouring Femtocell List. With the help of this proposed algorithm, neighbour list of UE is optimized. We can minimize the quantity of scanning and signal flux through the handover process by reducing the size of the neighbouring list in the integrated system.

In conventional algorithm, UE scans integrated network & prepare neighbour list according to RSS. The Proposed scheme consider RSSI & SON concept for selection of neighbour. As per SON concept, FAP next to the femtocell which is unseen (RSS not detectable) by UE due to obstacle, coordinates with unseen femtocell & takes location update and share it with UE to add it in neighbour list. Due to this, when UE moves towards unseen femtocell & cross obstacle then HO can take place.

G. Handover decision algorithm using Proximity concept

In femtocell network, it communicates with core network via internet so handover procedure is slower than legacy handover in macrocell network. Ayaskant Rath and Shivendra Panwar [18] proposed prefetch based fast HO algorithm to overcome slow HO issue. The procedure aims to prefetch or send higher layer data to nearby femtocells by decoupling the admission control & path switching process which takes place before and after actual handover of the UE [18]. Admission control process is replaced by quicker & much simpler Proximity Check process when ensures the target BS is already in the proximity of the UE. In this way it reduces the time spend in signalling as well as data exchange between the femtocell & the mobile core network during actual HO.

In this algorithm, author defined association region (region where femtocell signal is stronger than macrocell & other femtocell) and proximity region (surrounding region of association region). When UE is proximity region of one or many femtocell, copy of higher layer data send to all of them. Due to this, all femtocells in proximity region are ready for HO in near future & it reduces signalling time required for HO. In this way, suggested algorithm overcomes the drawbacks introduced by the usage of the public internet for message paths between femtocell base stations and the mobile core network.

V. CONCLUSIONS

In this paper, various handover management algorithms are studied and advantages, disadvantages of proposed algorithms are discussed. To develop novel approach of handover management in two tire macrocell-femtocell networks, we need to focus on various HO decision parameters, system model assumptions, QoS requirements and key features of algorithms.

Even though huge research is going on Mobility management in integrated macrocell femtocell network, few issues left unsolved in this area. This comprehensive survey of HO decision algorithms will give base to future research work in this field.

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