

# Design Specification for Reconfigurable Radio in Cognitive Communication

Olayinka Taibat Jinadu<sup>1</sup>, RafiuOluwadare Ijawoye<sup>2</sup>

<sup>1</sup>Department of Computer Science, Rufus Giwa Polytechnic, Owo, Nigeria

<sup>2</sup>Department of Electrical Electronics Engineering Technology, Rufus Giwa Polytechnic, Owo, Nigeria

<sup>1</sup>yimikajinad@gmail.com, <sup>2</sup>progressive.ijawoye@gmail.com

## ABSTRACT

Rapid evolution toward xG networks necessitates a user-centric approach where users can access different access networks and services using a single device equipped with multiple radio interfaces. Efficient mobility in converged network requires optimization of scarce spectrum resource. Cognitive Radio (CR) technology, defined by IEEE 802.22 enables mobile broadband communication and dynamic spectrum access. Significant underutilization of radio spectrum and limited co-existence of existing wireless systems are due to poor adaptations at routing nodes. These problems therefore, demand an innovative technology. CR network (CRN) model implemented as Software Defined Network (SDN) to detect white spaces by collaboration and reuse it opportunistically for communication. After capturing signals in target spectrum, spectral content is digitally processed for gain using pulse shaping algorithms. Received signal power on any multi-interfaced transceiver node equipped for mobility was measured using Network Simulator (NS2) tool. Communication was evaluated for throughput as routing nodes implement reconfiguration to deliver minimized packet losses and reduced overheads. Reduced signal fading as it moves farther away from home agents depicts accurate soft handoffs than in ordinary wireless communication. The model offered efficient spectrum mobility to provide seamless roaming. With pulse shaping and raised cosine approaches, cognition and reconfiguration technologies of CR are enhanced to facilitate smoother interoperability with lower standards. This alleviates the intermittent link availability problem suffered in mobile communication while faster handoff offer service continuity, eliminating limited roaming characteristics of existing wireless communication.

**Keywords:** heterogeneous, processing gain, spectrum handoff, spread signal, white space

## 1. INTRODUCTION

Next generation wireless system is characterized with modern wireless systems that must offer wide variety of high data rate applications to numerous users at the same time. Existing wireless networks and technologies including cellular 2.5G, 3G mobile networks and its evolutions as components of heterogeneous wireless-access infrastructure networks. These components operate optimally to provide high-speed reliable connectivity to the Internet anywhere anytime. For services integration, all wireless systems require efficient management schemes to cater for handoffs and spectrum mobility [1].

Spectrum allocation to different types of wireless systems including cognitive radio is done by regulatory agencies such as FCC depending on intended range of throughput requirement. Reference [2] identified mobile phones, WLAN modems and palm devices as cognitive radio types used for cognitive communications to deliver high data rates and wide range applications. To this end, wider target spectrum at lower frequency bands is assigned. In compliance with FCC regulations, transmission of cognitive radio sensed spectrum can be done via low power Ultra Wide Band (UWB) signaling because the spectral content of received signal can be analyzed either by analog or digital means.

Cognitive Radio Network (CRN), formed with routing nodes as a complex multiuser paradigm, implements artificial intelligent techniques to offer solution to spectrum scarcity problem using opportunistic approach [3].

References [4] and [5] explained CR learning capability as stages of spectrum sensing (detection of spectrum holes); spectrum analysis (collaboration and allocation); spectrum management (allocation or implementation of spectrum mobility) and spectrum sharing (reconfiguration to accommodate unlicensed). CRN configurations with infrastructure [6] or infrastructure less [7] architectures both support reconfigurations for adaptations.

In cognitive communication, design of transceivers for opportunistic spectrum usage is guided by three specifications: requirements for spectrum sensing, strategies of spectrum shaping and co-operation between transmitter and receiver. The transmitter or receiver has transmission and reception capabilities respectively. Reference [2] earlier explained transmission of spectrum-sensed results in UWB signaling as better accomplished in underlay manner, simultaneously with real data communication. Transceivers participate without affecting each other in CRN while each cognitive node (*cn*) transceivers are characterized with multiple technology specifications to enable collaboration with other participating CRs [8].

Major objective of this research is to specify parameters for signaling in CRN and to implement efficient pulse shaping for spectrum mobility on idle frequency bands. To occupy much white space, many CRs will share sensed spectrum information while reconfiguration algorithm and handoff techniques enables cognitive nodes (*cns*) communicate collaboratively to implement the UWB signaling specified for spectrum information exchange.

## 2. WIRELESS COMMUNICATION PRIMES

Diverse technologies such as GSM, GPRS, Wi-Fi, WiMaX, UMTS, EDGE, EV-DO, HSPA and cognitive radio included in heterogeneous network are enabled for spectrum handoff and mobility using techniques whereby MU maintains connection with home network (HN) while moving and/or changing connection point to APs. Reference [9] outlined the limitation of complementary wireless access networks, stating the strategies to overcome it as an integration of different technologies into a single unified next generation (xG) networks. Within heterogeneous network, limited roaming is associated with not too fast spectrum handoff, which also offers inaccurate spectrum mobility management techniques.

Although, current wireless systems are characterized by fixed spectrum assignment policy, xG network built with CR-based transceivers adopts IEEE 802.22 standardization to deliver broadband wireless access technologies and white spaces spectrum sharing [10]. These transceivers are cognitive nodes (*cn*). Guided by Orthogonal Frequency Division Multiple Access (OFDMA) technique implemented in Worldwide Interoperability for Multiple Access (WiMAX) technology [11], *cn* enable opportunistic spectrum usage. Also, these systems offer dynamic spectrum access, which hinges on effective handoff management strategies.

Roaming procedure of inter-operation among mobile users aimed at supporting user mobility across different service providers and communication technologies. Roaming enable wireless accesses in areas not covered by network service provided user does not have any prior arrangement(s). Roaming updates location information for roaming user and re-routing incoming user traffic to user's new point of attachment. While maintaining qualitative service with regard to user satisfaction, roaming must be seamlessly efficient [12]. Also, roaming enable MU gain access outside its provider's coverage using proactive algorithm implemented in SDR platform.

### 2.1 Spectrum Mobility in Wireless Networks

For heterogeneous wireless networks to coexist and use a common IP core to offer services, cognitive radio technology is employed to implement *spread spectrum* technique on orthogonally propagated signal of both licensed and unlicensed signals. This technique, when complemented with collaborating techniques delivers smart computing application requirement of xG even as Mobile Internet Protocol (MIP) designed by IETF support user's mobility for seamless roaming while enjoying other services on the Internet.

Heterogeneous access networks are characterized with various standards to offer high data rate multimedia services to end-users [13]. 4G and xG is purely IP-based access networks, converged as core network to evolve future networks. Therefore, for xG to seamlessly integrate various types of wireless access networks, intersystem roaming across existing packet-switched wireless access networks and high data-rate, high-speed multimedia services must include location-based services to offer higher mobility digital multimedia services.

Effective mobility management is an essential ingredient for seamless roaming [6]. Heterogeneous network conceptualized in Fig. 1 (appendix) enables *cognitive nodes* and *agents* use best available access network that suits its communication needs [13]. Reference [14] earlier observed that mobility management enable system locate roaming terminals and deliver packets while maintaining connection as they move across foreign networks (FNs). Mobility management techniques enable network track *cn* and as well update all information pertaining to consecutive communications. Therefore, interoperability techniques between diverse wireless systems must be characterized with efficient implementation of cognitive communication.

### 2.2 Spectrum Handoff

A spectrum hole is a white space. It is a band of frequencies assigned to a licensed signal but not occupied by the licensed signal at a particular time [4]. Handoff is a mechanism whereby ongoing connection between *cn* (mobile or fixed user) and correspondent cognitive node (*ccn*) is transferred from one point of attachment to an Access Point (AP) or Base Station (BS) on the wireless network to another. Through handoff, *cn* keeps its connection active even as it migrates from coverage area to another point on the entire network. Cellular and data network uses AP or BS to implement required routing functions during mobility as conceptualized in Fig. 1 and illustrated in Fig. 2.

Handoff security is provisioned in three stages of handoffs initiation, new connection generation and data flow control as specified for service delivery. Authentication processes is therefore a factor of handoff security, aimed at providing secured environment against all malicious attacks (including masquerading, replays, modifications, fabrications, denial of service and eavesdropping) on wireless networks.

### 3.0PARAMETERS FOR COGNITIVE NETWORK CONFIGURATION

Cognitive Network (CN), configured with cognitive transceiver nodes communicate data over defined coverage area. Each node implements mobility without breaking existing connections. Each cognitive node, assigned with IPV6 address has described home agent (HA) located on its home network (HN) as shown in Fig. 2 (appendix). Mobile cognitive node (*cn*)

leave its HN to attach to another foreign network (FN) to use another address called care-of-address (CoA) assigned by foreign agent (FA) on thenewly attached network AP. Mobility and sensitivity defined for these cognitive network nodes, scattered over a distance of 2000 metres(2Km)enables real life problem to be simulated using a Network Simulator (NS2). List of simulation parameters is shown in Table 1.

**Table 1: List of simulation parameters**

Parameters	Specification
Processor/OS/RAM	Intel Dual Core/ Ubuntu Linux 12.04, 4GB
Bandwidth/Geometric Centre Frequency	±1500MHz, 2.8GHz
NS-2 / OTCL version/ NAM	2.35/1.14/1.15
Frequency range	2.1 – 3.5GHz (HA, FA)
AOMDV, DSDV	NS default
Number of nodes,AP HA/FA	3,1, 2/2
Traffic Type	Variable bit rate / FTP
Simulation time	3600 seconds
Topology size	2000 x 2000m
Maximum speed /mobility rate	0.56m/s
Packet rate	2.9kbps (approx. 3packets/sec)
Number of transmitting/ receiving nodes	1, 3

Primary option of using *cns* to fill detected white spaces with unlicensed transmitting signal calls for major objective of using CR to implement pulse shaping to occupy as much white space as possible where licensed and unlicensed signals co-existed in an implementation of spread spectrum technique of OFDM[15]. Sub-carriers of unlicensed signals easily separated at receiver using raised cosine filter met up with this primary assignment.Orthogonal Frequency Division Multiplexing (OFDM) technique defined in (1)

was employed where  $x_q$  and  $x_k$  are signal functions representing licensed and unlicensed signals respectively. Transmitted signals, orthogonal over interval [a,b] is zero for any combination except for  $x_q(t) = x_k(t)$ .

$$\langle x_q \cdot x_k \rangle = \int_a^{bU} x_q(t) \cdot x_k(t) dt = \begin{cases} 1, & k = q \\ 0, & k \neq q \end{cases} \quad (1)$$

Given in (1), OFDM technique provide each CR with possibility of (i) multiple CRs coexisting with each other (ii) broadband transmission of licensed and unlicensed subcarriers and (iii) employment of spread signal technique, distributing transmitted signal data over a large number of subcarriers. The focus here is accurate pulse shaping technique for  $cn$  to implement spectrum handoff efficiently.

### 3.1 Cognitive Communication variables

As shown in Table 2, signal transmitted and/or received is measured to numerically represent normalized received power  $P_0$ . The simulation measurements showed an increasing signal fading at distances above 500m. As the cognitive receiving node moves farther away from transmitting source (home agent) as found with WLAN configurations, the fading increases. Highest signal fading occur at distances between 750 and 1000m. At distances above 1000m, signal fading is alleviated due to the presence of another AP, which acts as foreign agent (foreign network zone), which eliminated hidden node problem as receiving node become far from home agent. Fading become linear (moderately negligible) as cognitive node ( $cn$ ) moves farther away. this as a result of OFDM technique of signal spreading used and the intelligent reconfiguration of  $cn$  as it comes across another AP. Spectrum handoff is performed and inter-signal-interference (signal fading) is alleviated.

**Table 2: Throughput of transmission within coverage**

Distance moved (m)	Signal Transmitted (MHz)	Signal Received (MHz)	Observed signal fading	Throughput
50	1500	1495	5	-
100	1500	1484	16	11

250	1488	1457	31	15
500	1500	1455	45	14
750	1490	1418	72	27
1000	1480	1386	94	22
1250	1485	1390	95	15
1500	1483	1382	101	6
>1500	1493	1389	104	3

Each  $cn$ , equipped with multiple interfaces implements Gauss Markov Mobility (GMM) model to simplify movements. Time-dependent transition  $a_{ij} = P[q_t = j | q_{t-1} = i] \quad 1 < i, j \leq N$  was implemented by  $cn$  moving from HN to FN at instant time  $t$  within wireless network area defined and configured. While ensuring intended frequency spectrum is not in use, both parties of a communication (transmitter and receiver) scans entire spectrum to inform each other about spectral condition generally. Strategy for spectrum sensing incorporates an evaluation of opportunistic access to allocated bands. These conceptualized procedures of spectrum sensing and detection of white bands (including conceptual analysis) carried out by  $cn$  as it moves within CRN model in NS2 [16] represents transmission within coverage and out of coverage area/zones in the wireless network.

### 4.0 RESULT ANALYSIS

Each communicating node is enabled to implement cognition and reconfiguration for the cognitive system to simultaneously connect multiple APs with different access technologies. Soft handoff is performed based on accessible information from surrounding access networks. Reconfiguration using MIPV6 algorithm enables route optimization.

From Table 2, quality of received signal is linear over transmission distance of 100 – 1500m, which is sensitivity area of AP to AP. As  $cn$  encounters an AP, acting as FA, required routing function is implemented. Quality of signal received measured as throughput is also a function of Bit Error Rate (BER). Average Throughput measurements obtained is shown in Fig. 3. The throughput increases as  $cn$  moves farther from HA. Increased throughput is due to spectrum mobility provision by the signaling algorithm based on embedded reconfiguration techniques

effected at  $cn$  while implementing pulse shaping and processing gain algorithm is an implementation of Ultra Wideband (UWB) signaling techniques. Mobility rate of 0.56m/s was enabled.

Dynamic adaptation of transmission parameters with changing conditions of received signal demonstrated each  $cn$  implementation of spectrum sensing and management within sensitivity range of <2000m, representing estimated distance between APs. Also, minimal service degradation observed while moving showed linear signal fading even as  $cn$  moves farther away from sending nodes (APs). Cognitive nodes act as routing points to assist network provide reliable communication. Throughput measured shown in Fig. 3 showed linear signal fading at father distances.

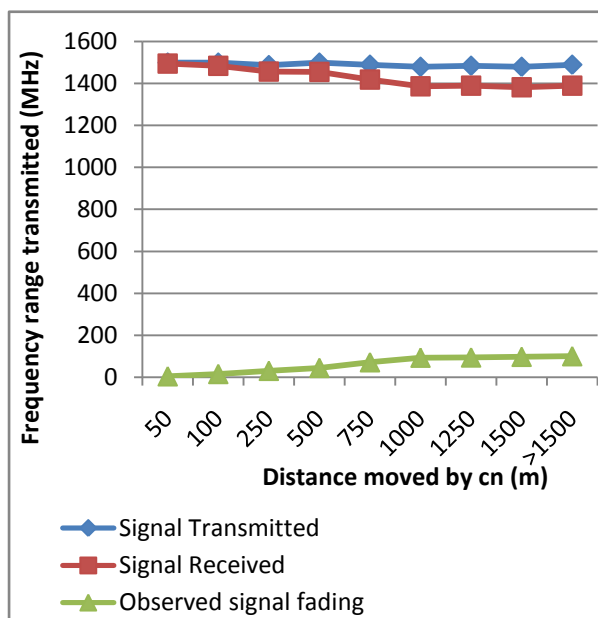


Fig. 3 Throughput measurement around coverage area

#### 4.1 QoS Evaluation

Each  $cn$  was modeled to implement Gauss Markov Mobility (GMM) model to simplify movement around the coverage area. Time-dependent transition of each node  $a_{ij} = P[q_t = j | q_{t-1} = i] \quad 1 < i, j \leq N$  was implemented as  $cn$  moves from HN to FN at instant time  $t$  within area defined in configuration in NS2. While ensuring intended frequency spectrum was not in use, parties in communication (transmitter and receiver nodes) were enabled to scan entire frequency spectrum to gather information about spectral condition generally. The strategy for sensing incorporated

evaluation of opportunistic access to allocated bands. This conceptualized procedure of sensing and detection of white bands, in conceptual analysis in NS2 represents transmission within coverage and out of coverage areas. As each  $cn$  periodically scan to detect spectra temporarily not used, distance moved was measured against transmission throughput. A strong relationship between received power,  $P_r$  and transmission distance  $d$  moved by mobile node is defined by (2) in [17].

$$P_r = \frac{P_0}{d^\alpha} \quad (2)$$

where  $d$  is transmission distance between transmitting nodes,  $P_0$  the received power at specified distance and  $\alpha$  the propagation medium constant ( $\alpha = 2$  for free space propagation). Received signal power increases when signal-to-noise-ratio (SNR) stabilizes as mobile node moves farther away from HA towards any FA. With this characteristic movement, hidden node problem and inter channel interference ( $ici$ ) bottleneck was alleviated. Also, noise vanishes away due to orthogonally transmitted signals. This capability also minimizes inter signal interference ( $isi$ ) bottleneck at receiving nodes.

Using formulated BER expression in on-off keying (OOK) OFDM modulation spread signal technique defined in [11], received signal quality is improved by turning on and off transmitted signals at different OFDM sub-carriers frequency. As suggested in [18], UWB signaling technique gives Received Signal Strength (RSS) measured in BER expression given in (3).

$$BER = Q \left( \sqrt{\frac{N_s A E_p}{2 N_0}} \right) \quad (3)$$

With pulse and amplitude parameters taken as unit quantities, received signal is normalized power where  $N_s$  is number of pulses per symbol,  $A$  the pulse amplitude,  $E_p$  normalized received signal power for  $Q$  number of detected white spaces.

Additive White Gaussian Noise (AWGN) filtering has double sided spectrum of  $\frac{N_0}{2}$ , eliminating duplicate acknowledgements, providing much reliability and bandwidth efficiency with lowered BER. Increasing  $N_s$  by repeatedly transmitting from  $cn$ s lowers BER because retransmission of non-acknowledged signal data effects *processing gain* illustrated in (3). The UWB signaling

technique enabled farthest *cns* access network information and sharesensed parameters. More so, UWB signaling eliminates allocation of separate channel for sharing sensed information. Use of centralized controller is not required as information collected is processed/transferred to other cognitive user and spread signal distribute data over all subcarriers.

Increasing network size is achievable viacollaboration. Sensed/received information from all nodes as common white spaces is subjected to pulse shaping for gain. Raised cosine filterdefined in (4) implements full utilization of all usable white spaces. Center frequencies  $f_{ci}$  and bandwidth  $B_i$  of each white space is determined as  $U_i$  for  $i = 1, 2, \dots, N$  transmitting signals, where  $N$  is total number of white bands.

In agreement with [2], each *cognitive node*determines filters  $r_i(t)$  suitable for its transmission having bandwidth and required data rate. Selected filters are then digitally multiplied with generated cosine signal to obtain (4) while shaped pulse is additively obtained for all detected white spaces expressed in (5).

$$\phi_i(t) = \cos(2\pi f_{ci}t) \cdot r_i(t) \quad (4)$$

Accurate pulse shape  $p(t)$ obtained as sum of separate pulses given in (5) is finally used to fill white spacesto implement spectrum mobility for handoff algorithm on emergence of licensed activity.

$$p(t) = \sum_{i=1}^N \phi_i(t) \quad (5)$$

Specified parameters in CRN implement efficient pulse shaping for spectrum mobility on detected idle frequency bands. Many collaborating CRs will share sensed spectrum information while reconfiguration algorithm and handoff techniques to occupy much white spaces. Cognitive nodes (*cns*) communicate co-operatively to implement the specified UWB signaling for efficient spectrum information exchange.

## 5. CONCLUSION

CRN communication paradigm enables the specified parameters deliver maximized frequency spectrum especially the entirely allocated bands than ordinary wireless systems. With improved RSS normalized power over cognitively sharedchannels,communication (propagation) is characterized with minimal path loss, Signal-to-Noise Ratio (SNR) and BER among others. This is also due to implemented OFDM technique, which eliminates all multiplying effect of congestion, *isi* and/or signal fading.Spectrum usage efficiency is thereby achievedand reliable communication obtained.Cognitive nodes intelligently implement learning and adaptations to changing environmental parameters (including signal strength) to deliver higher transmission throughputs.

Collaboration of multiple CRs withincoverage area having APs of different technologies is an implementation of coexistence of licensed and unlicensed subcarriers for accurate sensing. Improved detection of white spaces by the collaborating cognitive nodes also provide for fast handoffs and further maximizes reuse of scarce radio spectrum resource.

## 6.0 REFERENCES

- [1] S. Raman and N.P. Singh, An algorithm for spectrum sensing in cognitive radio under noise uncertainty, *International Journal of Future Generation Comm. and Networking*, 7(3), 2014, 61-68.
- [2] M.E. Sahin and H. Arslan, System design for cognitive radio communications. *In Proc. of the International Conference on Cognitive Radio Oriented Wireless Networks and Communications (CROWNCOM)*, Baltimore, MD, 2006, 380-385.
- [3] I.F. Akyildiz W.Y. Lee, M.C. Vuranand S. Mohanty, Next generation/dynamicspectrum access /cognitive radio wireless networks: a survey, *Computer Networks Journal*, Elsevier, 2006, 50 (13):2127-2159.
- [4] S. Haykin, Fundamental issues in cognitive radio. *In Cognitive Wireless Communications Networks*, edited by Vijay Bhargava and Ekram Hossain, Springer, 2007, 1-18.

- [5] W. Ejaz, N. Hassan and H.S. Kim, SNR-based adaptive spectrum sensing for cognitive radio networks. *International Journal of Innovative Computing, Information and Control*, 8(9), 2012, 6095-6105.
- [6] G. Ghosh, P. Das and S. Chatterjee, Cognitive radio and dynamic spectrum access- a study, *International Journal of Next-Generation Networks*, 6(1), 2014, 44-60.
- [7] P. Yadav, S. Chatterjee and P. Bhattacharya, A survey on dynamic spectrum access techniques in cognitive radio. *International Journal of Next-Generation Networks*, 4(4), 2012, 27-46.
- [8] O.T. Jinadu, F. Akinbohun and V.K. Owa, Collaborative sensing scheme for cr in xG networks. *International Journal of Advancements in Research & Technology(IJOART)*. 3(12), 2015, 23-29.
- [9] A. Garhwal and P. Bhattacharya, A survey on dynamic spectrum access techniques for cognitive radio, *International Journal of Next Generation Networks*, 3(4), 2012,.
- [10] IEEE 802.22 WG on WRANs (Wireless Regional Area Networks). Accessed 25/11/2015 from <http://www.ieee802.org/22/>.
- [11] P. H. Lehne and F. Bohagen, Orthogonal division multiple access OFDM(A) for wireless communication. *R and I Research Report*, Telenor, 2008.
- [12] Y. Yang and J. Wang, Design guidelines for routing metrics in multihop wireless networks. *IEEE INFOCOMM*, 2008, 1-9.
- [13] R.K. Singh, A. Asthana, A. Balyan, S.J.Gupta and P. Kumar, Vertical handoffs in 4G wireless networks. *International Journal of Soft Computing and Engineering*. 2(2), 2012, 481-490.
- [14] D. Johnson, S. Deering and C. Arkko, Mobility support in ipv6. RFC 3775, 2004.
- [15] O.T. Jinadu, *Development of cognitive radio wireless model for adaptive congestion control and spectral efficient communication*. PhD Thesis, Federal University of Technology, Akure, Nigeria, 2016, (Unpublished).
- [16] *The network simulator ns-2*. Accessed 51/3/2014 from <http://www.isi.edu/nsnam/ns/>
- [17] Z. Zhang, Q. Wu and J. Wang, Optimal energy efficient co-operative spectrum sensing in cognitive radio networks, *RADIOENGINEERING*, 22(4), 2013, 1150-1155.
- [18] R.B. Amira, D. Ayadi, I. Kammoun and M. Loulou, System level design for cognitive radio receiver – Application for IEEE 802.22 standards. *Electrical and Electronic Group, LETI Laboratory, Sfax, Tunisia*, 2011.

7.0 APPENDIX

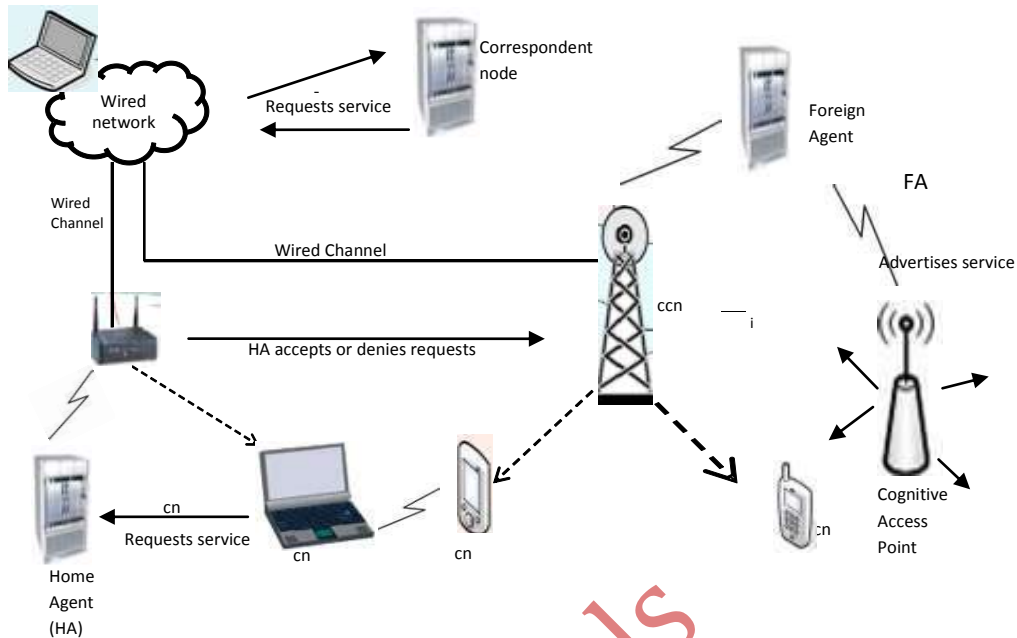


Fig. 1 Conceptualized heterogeneous wireless infrastructures

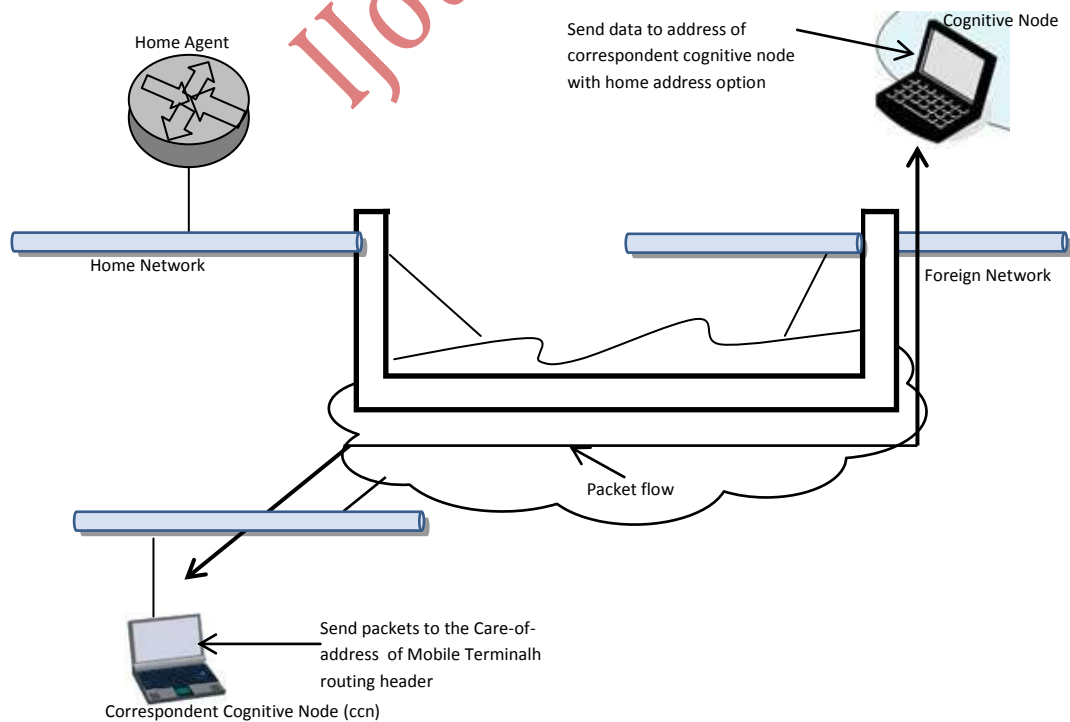


Fig. 2 Requirements for mobility and handoff