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# Multi-Access Support with Hybrid Handover Proposed for MANET Users and IEEE 802.22 Networks

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***Abstract* - Current wireless networks are challenged by user's increasing demand of high-quality, high data rate multimedia services as they move because globalization of numerous wireless opportunities increases with mobility. Mobile Ad-hoc Networks (MANETs) as networks with no fixed infrastructure or mobile nodesare characterized with multi-hop mesh networking where every host acts as a router. Mobile communications systems are targeted to support integration and co-existence of multiple radio access technologies (RATs) in composite radio environment. Mobile IP extends IP by allowing mobile node have two address while moving around in IPV6 and MIPV6 networks without breaking existing connection but mobility within IPV6/MIPV6 composite networks is characterized with limited interoperability. Attempt to support efficient mobilityin roaming and as wellenjoy other services on the Internet, end users required fast handoff to implement spectrum mobility and associated reconfigurationviasoftware defined radio (SDR). Accurate signaling on estimated spectrum capacityfor dynamic spectrum access is essential at communication instants when handing over is compulsory. Therefore, development of a wireless network selection algorithm (WNSA) as fitness function, using set of identified attributes, is the aim of this research. The fitness function is finally optimized to initiate an implementation of fast handoff and selection of best access network that offers high-quality service and unlimited roaming for MANET users.***

***Index Terms:*** **handoff, mobility, MANET, MIPV6, roaming, WNSA**

## I. INTRODUCTION

Several standardization groups are currently working on the incorporation of cognitive radio technologies, defined under IEEE 802.22 wireless area networks (WRAN), to utilize Television White Spaces (TVWS) and support future applications as smart grid networks [1]. The various forms of wireless network including Internet, 3G cellular, Wi-Fi (IEEE 802.11), wireless sensor networks (IEEE 802.15), worldwide inter-operability for microwave Access, WiMAX (IEEE 802.16) and body area network (IEEE 802.15.6) among others make up an heterogeneous network.

With these networks existing as *infrastructure wireless* (base station network connected to wired Internet);*base station* (communication through access points and fixed or mobile nodes), *ad-hoc wireless* (wireless nodes communicating directly with one another) or *Mobile Ad Hoc Networks* - MANETs (having moving ad hoc nodes), handover process enables mobile host (MH) switchingbetween domains of different access technologies[2]. Equally, as growing needs for wireless application ranges between smart grid network, public safety, broadband cellular and medical applications, and integration of these high resource-demanding networks require hybrid handover techniques [3].

Ad hoc network architecture illustrated in Fig.1consists of wireless nodes, which communicate directly in MANETs. Since all ad hoc nodesare well equipped for mobility, the architecture supports service integration. IP mobility causes change in IP address and multiple accesses to services by mobile or fixed hoststrategizes with location registration and spectrum handoff techniques [4].To provide broadband connectivity plus wide area coverage even as users move to utilize services from fixed (or mobile) network infrastructures, continuous qualitative service (QoS) requires distributed network management of all shared resources. Also, deployment of smart (software defined radio) systems in accessing resources for wireless service delivery inad hoc networks including MANETsis a concern for system designers because critical node movements characterize these wireless architectures depicted (Fig. 1).

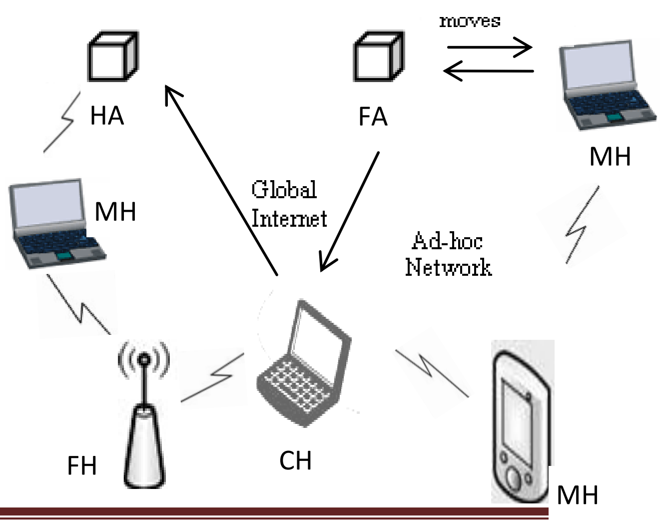

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**Fig. 1 Ad hoc network infrastructure**

Wireless and mobile technology providesubiquitous information access to users on the move. As next generation wireless systems offer overlapped Internet access, mobile Internet Protocol Version 6 (MIPV6) provides flexible and open architecture to support all the different types of networks, terminals and applications. Hence, integration of fixed and mobile infrastructures enable MANET users optimize network resourcesin composite radio environment [5].

MANETs and other ad hoc networks are characterized with unguaranteeddirect path and fluctuating service quality due to issues of dropping packets. This deteriorates asnodesbecame farther apart. Integration of the various wireless systems therefore, and resultant MANET require fast mobility of associated IP schemes even as intermediate correspondent hosts (CHs)route messages[6].Major issue of mobile host (MH) having access to its home network (HN) via foreign agent (FA) suggestsaneed for hybrid handover. Also, with trust as routing ingredient leveragingMHperformance with other MHs incollaborative utilizationof radio parameters discussed in [7], a wireless network selection algorithm is proposed to improve radio access by selecting the best available point of attachment (POA)to facilitate smooth handover in mobility.

## II.MOBILE COMPUTATION STANDARDS

Iterated in [1] and [7], wireless mobile communications are extensively used for emergent response environments where responders such as police, fire and emergency medical applications/services, prevent or respond to incidents, and users obtain quick-access emergency services. Public safety workers are increasingly equipped with wireless laptops, handheld computers and mobile video cameras to improve efficiency, visibility and ability to instantly collaborate with central command, agencies and co-workers. Wireless services for public safety had extended from voice to messaging, email, web browser, picture transfer, database access, video streaming, video surveillance and other broadband services. Correspondingly, data rates and transmission reliability requiredvary from network to network [8]. This requirement is met to alleviate interruptions and service degradation, which characterizes mobile computations.

IEEE has many groups currently working on developing standards toimprove mobile communication even in white spaces (TVWS). Categorically, IEEE 802.15 study group (SG) is created to investigate the use of TVWS whileIEEE 802.22 working group (WG) was created for TVWS-based wireless regional area networks (WRANs) covering 10 - 100km range and large scale smart grid networks; IEEE 802.19.1 WG was created for wireless coexistence of CR users in TVWS andIEEE 802.15.4g WG was created for smart meters operations and smart utility networks (SUN). IEEE 802.11af WG super-headed development of IEEE 802.11 amendment drawn for TVWS operation in WLANs whereas Medical Body Area Network (MBAN) was created as an application targeted at opportunistic use of underused frequency band (2360 -2400 MHz) [9].

***MANET features for mobility***

In MANETs, computation involves each mobile user node having two addresses and using one for identification while the other is used for routing. TCP keep track of all internal session states using IP address of the two endpoints. While using this IP address to find optimal route based on specified routing algorithm, mobile nodes determine its point of attachment either at home network (HN) or a foreign network (FN) using MIPV6. MIPV4 and MIPV6 support node mobility described in [4] used *agent discovery*, *registration* and *routing* updated with trust implemented in trusted carry-forward (TCF) algorithm.

When MH detects available access network and get authorized to use resources/services, BS/AP fixed within coverage area serve as foreign host (FH) to the MH and/or CHs. To inform MN about its loss of connection therefore, becomes necessary such that new technique of discovery, registration and routing may be initiated for continued service quality in roaming. Mobility management discussed in [10]composed of two components of location and handoff management. Handoff is the mechanism whereby MN keeps its connection active when migrating or roaming from coverage area of one access network attachment point to another with similar or different technology.

MIPV6 provide mobility support for IPV6 protocol at network layer [11]. IP extension and technology allow integration of heterogeneous networks into single all-IP based, integrated platform for MIPV6 to create new method of return routability procedure to share secrets between MHs and CHs as suggested by [12]. This spectrum sharing phases indicated in Fig. 2 provides address proof of ownership on binding messages sent to FH via FA from HA[13].As MH roams away from home subnet in MANETs, MIPV6 implementcentral data structure cache at HA for CH to learn and cache for update of care-of-address at FAs.

***Spectrum mobility and handoff technique***

Spectrum mobility as management technique includes spectrum sensing, spectrum decision, and spectrum sharing and associated spectrum handoff. Functionality of spectrum mobilityis major goal of transferring connection to vacant band on appearance of licensed user. With mobile user regarded as ‘visitor’ to unused spectrum band, specific portion of spectrum used for communicationmust be shifted for such communication to continue on another vacant portion of spectrum using spectrum mobility techniques.

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Identified in two forms as horizontal and vertical handoffs, both schemes enabled MANET hosts operateeither as intra-system (between APs or BSs of same network technology) or inter-system (between different POAs on different network technologies) and communicate to maximize link utilization [14]. Existence of heterogeneous communication technologies andprotocols offeredMANETs differing MAC and PHY structure for integration and provision of better services at upper (application/service) layer while optimizing lower layer resources[15]. This capability is essentially handled by reconfigurationtechniques defined in SDR, which is analyzed in [16] and implemented in [17].

## III.MATHEMATICAL FRAMEWORK FOR NODE MOBILITY

Spectrum mobility occur in wireless network when secondary system (FH), communicating on licensed frequency band while primary system (MH) is not using the allocated spectrum, transfers its communication to free spectrum band on the appearance of licensee. The FH visits jumps to a foreign network to continue its communication, possibly using FA service. Technically, using free spectrum while licensee is inactive and jumping from this specific portion of the spectrum when required by the licensee to continue communication on another vacant portion of the spectrumdescribe spectrum mobility concept. This technique make network layer protocol transparent to handoff procedure while latency ofchannel operating parameter becomes easily adaptable for SDR reconfigurations [17].

Network layer interface between communicating point-to-point (access) and end-to-end (transport and application) technologies played major role the integration process for mobile users to selects best communication system to fulfill her demands. MANET nodes contain target applications used in battle field, border patrol or disaster recovery. Within the home agent (HA) in HN, MH is assigned with permanent IPV6 address. Internet Protocol (IP) in TCP/IP stack therefore, implements mobility management at network layer as shown in Fig. 2. Mobility management via spectrum decision facilitates handover. The flexibility inspectrum mobility and associated handoff achieve ultimate goal of SDR for both link and end-to-end reconfigurationbetween host A and B illustrated in modified architecture presented in Fig. 2 [18].

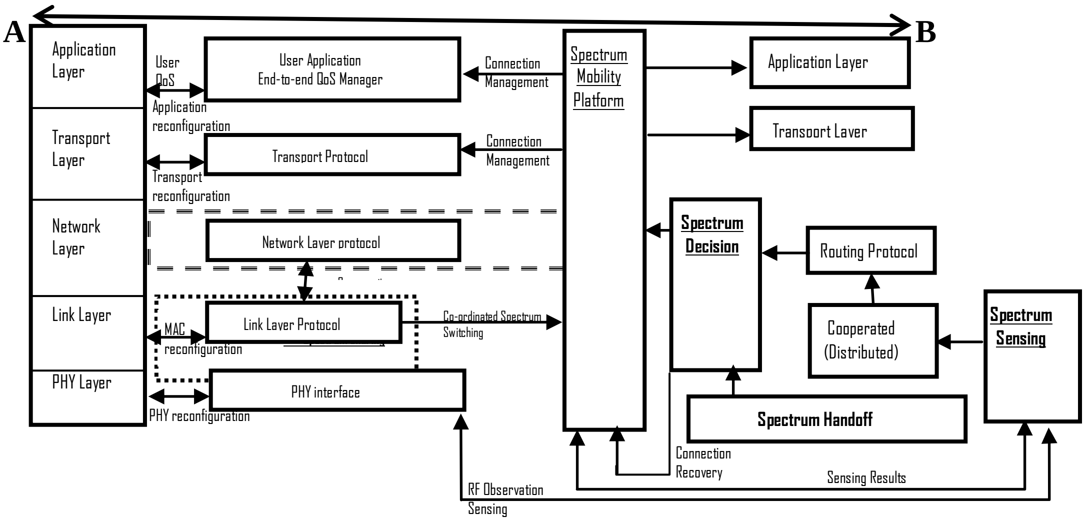


**Fig. 2Spectrum mobility architecture in MANETs**

MIPV6 protocol implementation and associated connection management (within the spectrum mobility platform) facilitates handoff when: (1) licensee is detected on used portion of spectrum, (2) MH loses connectionin an on-going communication due to mobility or (3) current spectrum band cannot provide QoS requirement and control of service need to be continued on another spectrum block (band).Smooth handover is therefore a function of both the available link capacity and mobility technique employed.

Analyzed in [19] and used in [20], given portion of spectrum is divided into $\beta$ channels sensing blocks (csb) to be sensed for detection of idle spectrum for mobility and handoff operations indicated in Fig.2. Each block contains $\alpha$ channels of width $B_c$ where $B$ is allocated bandwidth and $\alpha = N/\beta$, for $N$ nodes in MANET. This spectrum block $B_c$ is therefore a slice of available spectrum and $B_{csb} = \alpha B_c$ is determined by MAC/link and PHY layers. Frequency interval $f_0, f_0 + \Delta f_0$ and time interval $t_0, t_0 + \Delta t_0$ for transmission in MANETs is as applicable to other networks.

Performing network layer handoff, new IP address acquired at new POA (FA) used inhandoff process begins with MN determination of best quality access network reachable and laterthe determination of handoff style.to

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adopt. Upward or downward handoff is then facilitated via spectrum mobility; more so, assoft handover execution concerns all entities at ad hoc and global network levels. Reference [13] contain procedures of how MHobtain a care-of-address on the foreign network (FN)and control of the MH is handed over to FH's access point (AP) or base station (BS). After initiation step, agent discovery and registration procedures,implemented in MIPV6 protocol make mobility agents determine POA of MH with either HA or FA [21].

Arising from spectrum sensing and observed radio frequency stimuli, operating parameter metric for MANET nodes estimated for spectrum decision (Fig. 2) is expressedas $C = B\,log\left(1 + \frac{S}{N+1}\right)$in agreement with [22]where $B$ the bandwidth for $S$ received signal power at the receiver is characterized with$N$ noiseand $I$ interference. Capacity analysis is used to investigate the ultimate performance limit and potential application of MANET system since the available bandwidth at each link is the unused capacity [2]. Bandwidth and time duration of spectrum block used in decision are tuned to perceived intensity (received energy or signal strength) [5]. Available spectrum resourceneeded by MH to transmit and receive simultaneously through channels operating on different frequencies is characterized with operating parameter identified as performance metrics.

***Performance metrics for WNSA***

Performance metrics discussed in [6] and modified in [7] depicts a generalized, framework for multiple accessesin heterogeneous network. Channel capacityis first analyzed via spectrum sensing. Formulated network selection algorithm takes these metrics as input data forMH to select optimum access network and channel best suited for communication. Enumerated attributes selectedto represent performance metrics includes:

(i) *signal strength (S)*: indicated by availability of network, detected with good signal strength;
(ii) *network coverage (c)*: large coverage area network enables mobile users avoid frequent handoffs while roaming;
(iii) *data rate (D)*: network that can transfer signals at a optimum high rate is preferred;
(iv) *Low service cost*: Cost of service offered as major consideration for user's choice of access network and subsequent initiation of handoff;
(v) *Reliability (R)*: reliable network is trusted to deliver high level of performance for fault-tolerance;
(vi) *Security (S)*:network with high encryption is preferred for confidential information exchange;
(vii) *Mobile velocity (V)*: handing off at high speed to an embedded network in overlay architecture of composite radio environment (heterogeneous access networks);
(viii) *Battery power (P)*: Power consumption minimized since mobile devices have limited power capabilities and as battery level decreases, handing off power limitations lead to poor decisions and
(ix) *Network latency (L)*: low (minimized) time taken to achieve information transfer within MANET as high network latency degrades service/application performance and information transfer.

## IV. EVALUATING HANDOFF METRICS

With Good signal strength (S); Good network coverage (A); Optimum data rate (D); Service cost (C); High Reliability (R); Strong security or high encryption (E); Good mobility of average velocity (V); Low battery for power consumption (P) and Low Network Latency for fast handoff algorithm (L) identified as set of operating parameters to initiate handoff, a fitness function defined for WNSA is given in (1).

$$f_i(x) = f\left(S_i, A_i, D_i, \frac{1}{C_i}, R_i, E_i, V_i, \frac{1}{P_i}, \frac{1}{L_i}\right) \quad (1)$$

This fitness function becomes

$$\sum_{i=1}^{6} w_x \cdot N_f(X_i) + \sum_{i=1}^{3} w_y \cdot N_f\left(\frac{1}{y_i}\right) \quad (2)$$

Where $N_f(X)$ *is* a normalized function of parameter $X$, $w_x$ is weight of parameter $X$, $w_y$ the weight of parameter Y. $X_i = \{S_i, A_i, D_i, R_i, E_i, V_i\}$ and $Y_i = \{C_i, P_i, L_i\}$.
For identified parameters to jointly initiate handoff with Xset of input parameters to optimize the link and as well deliver high-quality service, normalization $N_f(X)$ is obtained for parameter $X$ as fuzzy membership function $\mu X$ with respect to *maximum* and/or *minimum* values of the identified real-world parameters.
Thus, the fitness function becomes (3) where all identified parameters are measurable in communication instants with MHs.

$$f_i(x) = \sum_{i=1}^{6} w_x \cdot (X_i / X_{max}) + \sum_{i=1}^{3} w_y \cdot (Y_{min} / Y_i) \quad (3)$$

Therefore, set of input parameters needed to providehigh-quality service is finally obtained as a fitness function described in (4) where $f_i(x)$ is the fitness value for*MANET* within the global Internet where$w_j$ is the weight of the parameters,$\mu C_j$ the degree of membership of each metric by fuzzy reasoning using Fuzzy Inferencing Set for $\boldsymbol{A_i}$set of link attributes.

$$fi(x) = \sum_{j=1}^{N} w_j \cdot \mu_{C_j}(A_i) \quad (4)$$

***Optimizing WNSA***

Technically, softhandoff implemented in SDR model described in [7]makes connections before breaking occurs as MH moves while communicating. Possibility of establishing connection with more than one POAsin

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mobility is enabled to augment MANET performance. Capability of IEEE 802.22, 802.22a and 802.19.1 technologies in frequency reuse implementation provides an agile configuration to optimize proposed WNSA.Therefore, an access network for MH to initiate handoff and associated spectrum mobility is selected whenever fitness function satisfies the optimized expression formulated as given in (5).

***Subject to x***

Maximized $f_i(x)$ therefore select best access network after evaluating the defined objective function. For MANETs, $x$metrics is measured to initiate handoff for fast spectrum mobility. Optimized WNSA thereby enhance smoothhandover as suitable normalized function of parameter $X$ is obtainable as a fuzzy membership function $\mu X$with fuzzy set of measured data. Parameter value normalized between 0 and 1 is capable of implementing slow and fast for service continuity to establish unlimited roaming.As optimized WNSA assist MH in handover procedures.Finally, in agreement with [2] and [11], service degradation and interruptions while moving around is significantly alleviated due to simultaneous communication enabled for MH during handing over; MIPV6 address management; best access network selection (efficient POA) and associated traffic redirection (due to handover)..

## V. CONCLUSION

Main purpose of optimizing WNSA is to improve the radio access ability of MANET MHs. Through self-healing and reconfigurationprovided by IEEE 802.22 technology [23], smooth handover is facilitated in MANETs. With ad hoc host connectingwith high speed to upper layers of another ad-hoc using hybrid handovers (vertical/horizontal/inter system/intra system), MANEToffers scalability as all correspondent node are routers [24]. The soft handover technique via SDR when implemented in MANET will surely deliver a dynamic spectrum access (DSA) and associated maximized spectrum utilization [25].

In like manner, WNSA incrementally selects best resource to incorporate fast and smooth handover for optimized high-quality service and self-healing configuration, which provide interoperability with existing wireless technologies [26]. With optimized WNSA, MANEToffers more resilient, scalable and better quality communication than ordinary wireless networks because location management by MIPV6 helps tracks MH for successful information delivery while active connection is maintained for unlimited roaming by WNSA.

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