Network and Complex Systems
ISSN 2224-610X (Paper) ISSN 2225-0603 (Online)
Vol 1, No.2, 2011

Soft Handover scheme for WSN nodes using media independent handover functions

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Abstract

The present wireless networks are equipped with multiple radio links and operate in a collaborative way to enable continuous data transfer even when any link goes down. The IEEE 802.21 is a standard to provide continuous wireless connectivity between heterogeneous link technologies using media independent handover functions as MIHF. The standard supports handover between IEEE 802.11, IEEE 802.16, 3GPP cellular networks. The wireless sensor networks (WSN) based on IEEE 802.15.4 consists of sensors to monitor various physical or physiological activities and to transfer the collected data to the remote controlling station using a short range radio. But in this case if the wireless node moves out of each other's communication range data transfer is not possible. So in this paper, the WSN communication protocol is made as a part of the IEEE 802.21 stack to explore the handover feature offered by the standard. The proposed stack has an internal partition to make WSN protocol to operate independently with other similar modules as long as they are in range, and the MIH function gets triggered by the application when the home networks are not available thus to provide handover from other link interfaces.

The proposed hardware has IEEE 802.11, IEEE 802.16, and 3GPP links which are operated by the MIH functions along with the IEEE 802.15.4 interface. So the WSN modules are provisioned to have connectivity from multiple radio interfaces even if they move out of the coverage range from the current point of access. The proposed primitives for handover between WSN and other links are efficient in providing reliable handoff.

Keywords: IEEE 802.21, Media independent handover, IEEE 802.15.4, Wireless sensor network.

1. Introduction

Wireless sensor network based on IEEE 802.15.4 standard [1] consists of autonomous sensors spread over a geographical region to monitor some of the physical events like temperature, pressure, humidity and communicate the monitored data to a central controller or network coordinator by forming a short range wireless network. In this case the data transfer is possible as long as the coordinator and the node are in communication range of each other. Whenever they move out of the physical coverage range, the node becomes orphaned. Adapting to different network topologies can give only a temporary relief. In a wireless environment there will be multiple radio links operating each with different coverage range. In present day wireless nodes it is common to find multiple radio links which coexists in the same transceiver and operate in a coordinated way. As an example a 3G mobile phone equipped with GPRS and Wi-Fi interface for internet access. As the Wi-Fi has limited physical range, the user can access the internet services using the GPRS link if the Wi-Fi access is not available. .

The IEEE 802.21 is a standard [2] to provide wireless connectivity between different wireless link technologies, i.e.802 or non 802 links, in a coordinated way by performing handover between them. Due to this even if the user moves out of the coverage area of one network, the other networks will be available to have continued data transfer. It supports horizontal and vertical handover between IEEE 802.11 WLAN, IEEE 802.16 Wi MAX, 3GPP cellular networks using a set of functions called Media Independent Handover Function MIHF.

It provides three types of services namely event, command, information services to the layers above or below it when incorporated into a protocol stack. The architecture of the IEEE 802.21 has higher layers consisting of MIH users which initiate the handover process by commanding the underlying MIH functions. The MIHF provides event services to the higher layers as MIES which deals with reporting of events related to the changes in the link behavior, link status like link up, link down, or any changes in the link parameters. These events can be generated from any lower layers within the protocol stack.

Media independent command services (MICS) are generated by the higher layers which enables them to control the physical, data link layers to establish the network connectivity based on the status, and dynamic behavior of the links. Thus MICS enables MIH users to select the best network and to control its behavior.

Media independent information service (MIIS) consists of gathering the entire network information of all the networks operating within a physical region including their network type, address information, offered services. This information is used by a MIH enabled mobile node to access the available networks when it is out of the coverage area of its present serving network.

There are several works on the MIH which discuss to provide efficient handover between IEEE 802.11 and IEEE 802.16 links [3]. It also uses new scheme of candidate deployment and tries to provide connectivity between 3G and IEEE 802.16 networks also. The formation of framework for MIH [4] [5] to provide connectivity between 802 links provides easier and faster handover. In [6] cross layer based approach is used to provide handover between the 802 and cellular networks by using the network selection policy engines and new mobile node architecture. By considering the mobile nodes, the handover implementation issues are simulated in QualNet [7]. For efficient handover, an information server is designed with in the new architecture and prototype is evaluated in [8]. The results shows optimum processing time in handover and it varies based on the application. The RIWCos architecture for reconfigurable hybrid networks is discussed in [9] with the detailed view of components of RIWCos link layer with the primitives for link interoperability. It has implemented Bluetooth as a link with in the stack to provide handover. To collect the handover information from the information servers effectively centre node architecture is proposed in [10], which collects information from all servers to update the network [11].

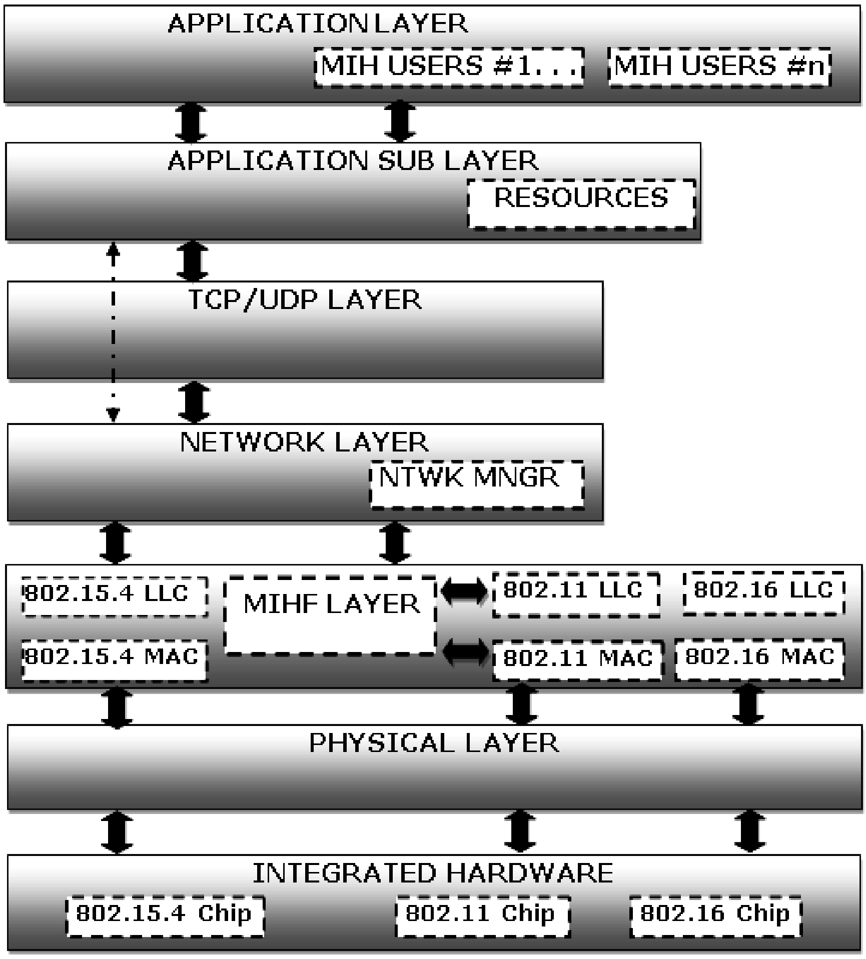
In all the existing works, the MIH features are explored to have connectivity between 802 or cellular networks. But in this paper, the MIH is used to trigger the handover process whenever the WSN nodes loose connectivity with the coordinator to continue the data transfer. Thus in this case the wireless node is called as Mobile Node (MN), is a portable wireless unit which has multiple wireless links and also the MIH. The IEEE 802.15.4 based protocols which is used for sensor based inter node communication is also the part of the same MN [2]. Initially the WSN nodes communicate to have data transfer as long as those devices are in communication range of each other using 802.15.4 link, but when they move out of the coverage area, the application layer of the integrated heterogeneous wireless unit invokes the MIHF to perform the handover services using other wireless links like IEEE 802.11, IEEE 802.16, or 3GPP networks in order to have continuous data transfer. This is done with the help of a central data base which keeps track of all the network information called MIIS server. All the networks are connected to the MIIS server either directly or via their point of services (PoS) to share this information.

2. The node architecture

The node architecture consists of '7' layers; the application layer invokes the task functions to initialize the entire stack as soon as the device is powered ON. It also has application objects and MIH user functions. This stack in -houses IEEE 802.15.4 protocols along with the Media Independent Handover (MIH) functions to facilitate the handover process. But the WSN protocols and MIH functions are separated, due to the reason that the IEEE 802.21 MIHF does not specify about its support to IEEE 802.15.4 standard. The MIH user feature allows configuring various services between different network elements. The application objects are used to map between different sensor applications

The application sub layer is initiated by the application task; its functionality includes initialization of buffers from the recourses pool and hand it over to the required layer for the transportation of data.

As this stack provides support for the internet based data, the TCP-UDP layer is included to provide connection oriented or connectionless data services to the different link technologies. The UDP due to its light weight nature is most suitable for the power conservative wireless modules. As shown in the figure, the WSN data communication is bypassed with the TCP/UDP layer.



Fiure.1 Mobile Integrated Node architecture

The function of the Network layer is to provide routing information and to offer various addressing mechanisms to easily facilitate the data transfer within the network. The network layer also has the responsibility of address translation for the data packets which emerge from different link technologies. The network manager (NWK MNGR) module within the network layer maintains the data base of all the link addresses from different networks when being broadcasted by the newly joined network elements. The security functions associated with the network are also be initiated by the network layer. Currently in the proposed stack, the security module is not shown for the sake simplicity.

Media independent handover function is the core of the protocol stack in providing media independent handover services. It provides event, command, information services to the layers within the stack and also gathers information from the MIIS server which may be located anywhere in the network to provide information about heterogeneous handover. Usually MIIS server will be located in such a position to enable all the MNs to have access at least by a single link.

There are separate link layers for each standard like IEEE 802.11, IEEE 802.16, and IEEE 802.15.4 to enable (support) respective hardware to get connected. The devices communicate via respective medium access protocols while accessing the wireless channel. The IEEE 802.15.4 LLC and MAC are separated from the main stream as indicated in the node architecture.

Hardware layer has functions to control the underlying hardware during data trans-reception operation. Handling of transceiver timing, interrupts, operating states are controlled by this layer.

The hardware being the integrated hardware which includes transceiver IC's to support IEEE 802.15.4, IEEE 802.11, and IEEE 802.16 while providing handover.

3. The general scenario

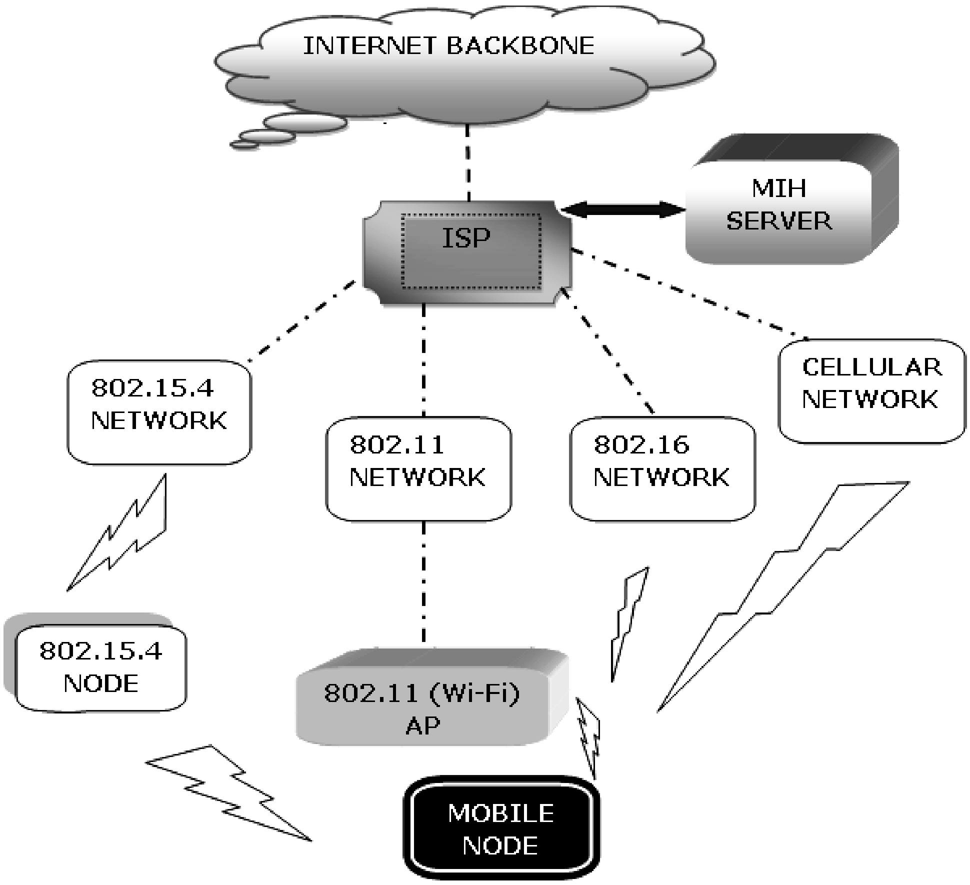
The wireless environment consists of different wireless technologies operating within a geographical region as shown in the figure 2. It consists of IEEE 802.11 enabled WLAN, IEEE 802.16 enabled WiMAX, 3G cellular network, and IEEE 802.15.4 enabled WSN modules. As the physical ranges of these technologies are different, to provide continuous coverage, the wireless nodes operate in a coordinated way. The IEEE 802.21 a standard for heterogeneous handover, which enables the handover between WLAN, WiMAX, 3G networks. It consists of a set of functions defined as MIHF (media independent handover function) and is also served by an external server named MIIS media independent information services) server. The MIIS server (MIH server) gathers all the networks information and communicates with the MIHF of the device to provide the required information to allow continuous uninterrupted wireless services.

As shown in the figure, where all the wireless networks are being served by the internet via internet service provider (ISP). The client devices are MIH configured mobile units which are compatible with all the wireless link technologies. Here the source client node (MN) has to transfer the gathered sensor data to the sink (coordinator) using IEEE 802.15.4 link. During the time, if the source client moves out of range of the IEEE 802.15.4 link, the application layer within the MN invokes the MIH function to get information about all the networks operating around using 802.11 link via internet (Instead of 802.15.4, as MIH does not specify about 802.15.4).The MIH server which is connected to the internet backbone has all the network information collected from the network elements. As all the networked devices broadcasts the network information during its association with their sinks or point of access, the MIIS server can inform the client about all the surrounding networks via the same link. Thus the MIHF can decide about the handover process.

4. Implementation

As long as the client2, i.e. the mobile node is being served by the WSN coordinator, the handover process is not triggered; and the mobile node acts as an ordinary WSN module. But when the signal received by the WSN coordinator to the mobile node reduces below a threshold the MIH process is triggered by the application. Thus the MIH is separated from the IEEE 802.15.4 standard as IEEE 802.21 standard doesn't specify about this. In this paper the handover for the WSN data is done with the help of MIH functions in coordination with the other wireless network standards. So whenever the node fails to get fair signal strength from the serving WSN station, the application triggers the hand over procedure.

If the mobile node moves away from the coverage area of the coordinator, it may happen to miss the successive beacons from the coordinator indicating that the node orphaning. To avoid this by providing continuous communication, in this design the application support layer is made to trigger the handover process by enabling the IEEE 802.11 chip of the integrated hardware to collect the network information. The flow chart of the implementation sequence is shown in figure 3. The MIH function instructs the IEEE 802.11 transceiver within the mobile node to gather the network information from the MIIS server. The MIIS server transfers all the required information from its data base to the MN using the 802.11 link. Based on the obtained information from the server, the MN decides the best network element as its future coordinator to get connected with. During this phase in the design a preference is provided. I.e. the MN prefers the future coordinator network as in the order 802.11, 802.16. 3GPP. If the highest preference network is not available, only then it selects the networks of lower preference.

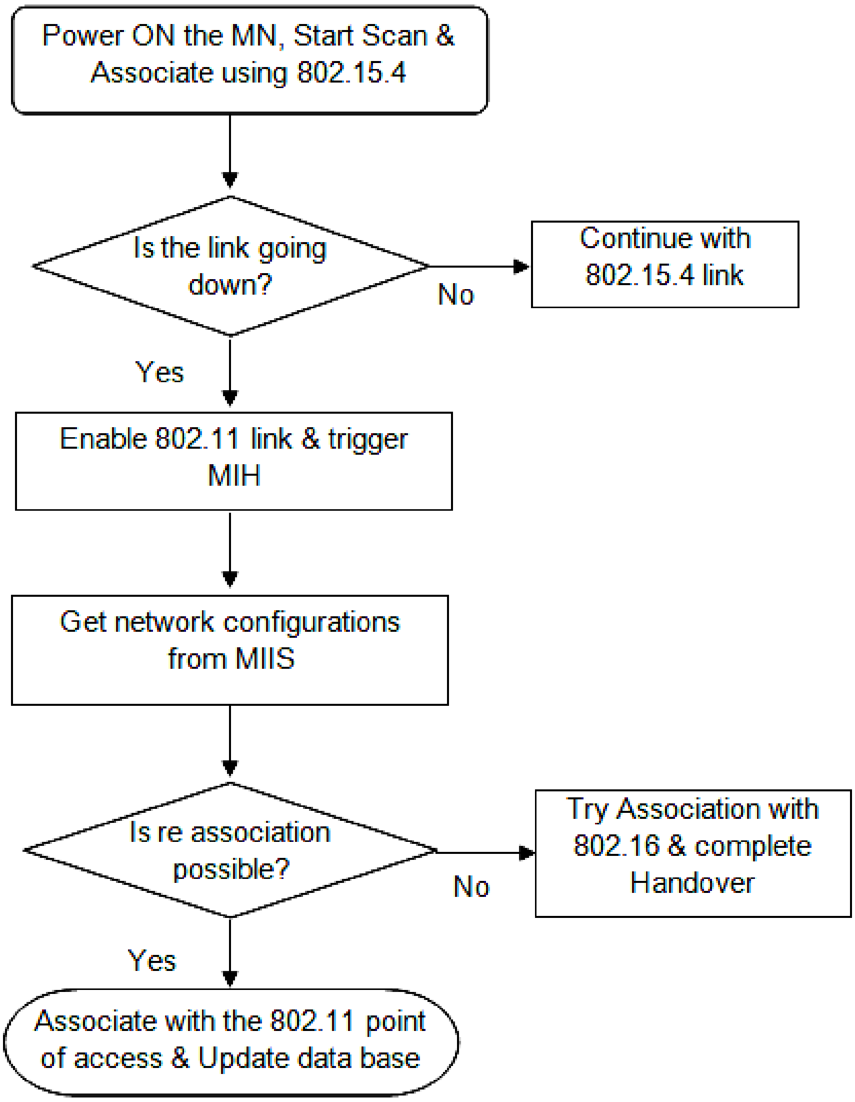


Fiure.2 Mobile Integrated Node architecture

Thus if the 802.11 networks are not available then it tries to join the 802.16 network. This process has to be done before the IEEE 802.15.4 link between the coordinator and mobile node gets terminated. The mobile node prefers to join the coordinator's network by default, but if the coordinator has moved away from the coverage area then the node can join other network elements based on its preference list. To join the network of the coordinator of its choice, the node associates using 802.11's association primitive or it has to re- register using MIHF primitives by sending its capability information to the associating network element. This process has to be carried out under the supervision of the MIIS server.

5. WSN scan and association procedure

In the following sections the network formation by the WSN nodes are demonstrated. Initially as soon as the MN is powered ON, the IEEE 802.15.4 protocol is made to get enabled by default. It scans all the surrounding WSN networks by enabling its transceiver. The WSN coordinators operating in its neighborhood send their beacon details to the MN. Based on the received information, the MN selects the coordinator of its choice to join its network which is termed as association. After the association with the WSN coordinator, the MN performs the data transfer.



Fiure.3 Implementation sequence flow chart

Initially as the node gets ON, the application sub layer initiates the scan process to determine the surrounding wireless networking entities to form a network with them for the data transfer. As per IEEE 802.15.4 specifications, the scan process can be done in two ways i.e. active scan where the initiating node sends the beacon request to the surrounding IEEE 802.15.4 coordinator entities, on receiving the request the coordinator nodes will transmit the beacon to the requested node indicating the details required for association with it. In passive scan the node waits for the beacon frames from the operating coordinators in its surrounding to form association with anyone. In IEEE 802.15.4 standard to form a network between a child node and the coordinator by forming the network, the child nodes (unassociated) searches for the coordinators which are operating nearby by performing the scan process. The scan process is performed on each channel to find a signal on that channel which of sufficient strength. While performing the scan process the PHY layer enables the transceiver in reception mode to collect the quality of the signal for a scan duration period. After the elapse of this duration it shifts to the next channel in the list of channels provided by the higher layers. After successful scan of all the channels, a report will be prepared based on the quality of the received signal and a decision will be made about the selection of channel to join the *network* of that particular coordinator.

5.1 Scan Channel process

The communication between each layer is shown in figure 4, in terms of primitives which consist of sending a set of parameters between the layers.

The Application Sub layer initiates the scan process by sending the *NLME-FIND-NWK.request* primitive to the Network layer indicating the list of channels to be scanned to discover the networks operating within the device's personal operating space (POS) . Thus the network layer instructs the MAC layer to perform the scan process by enabling the transceiver in reception mode. The Application sub layer sends the following main parameters:

NLME-FIND-NWK.request

{ *Scan Channels, ScanDuration*

}

On receipt of this primitive, the NWK layer will attempt to discover networks operating within the device's personal operating space (POS) by performing an active scan or passive scan over the channels specified in the Scan Channels argument for the period specified in the Scan Duration parameter. The scan is performed by means of the MLME-SCAN. request primitive. On receipt of the MLME-SCAN.confirm primitive, the NLME issues the NLME-FINDNWK-confirm primitive containing the information about the discovered networks with a Status parameter value equal to one that returned with the MLME-SCAN. Confirm.

The MLME-SCAN. Request primitive is used to initiate a channel scan over a given list of channels. A device can use a channel scan to measure the strength of the signal on the channel, search for all coordinators transmitting beacon frames within the POS of the scanning device. The MLME-SCAN. Request primitive is generated by the NWK layer and issued to its MLME to initiate a channel scan to search for activity within the POS of the device.

The active scan is performed on each channel by the MLME first sending a beacon request command. The MLME then enables the receiver and records the information contained in each received beacon for *ScanDuration* period on each channel as specified in the Channel list and generates a report containing the scanned details. Based on the MLME-SCAN. Confirm report, the higher layers will decide about the best coordinator to join. Thus the parameters in the received beacons of the surrounding coordinators play a vital role.

On receipt of this primitive, the next higher layer is notified of the result of its network search with the list of coordinators operating in its POS. The status indicates SUCCESS if search was successful else error. Then the ASL proceeds to start the association procedure by selecting a coordinator obtained from the scan process. The selection of the coordinator is based on the *PANId, RSSI, LinkQuality* parameters.

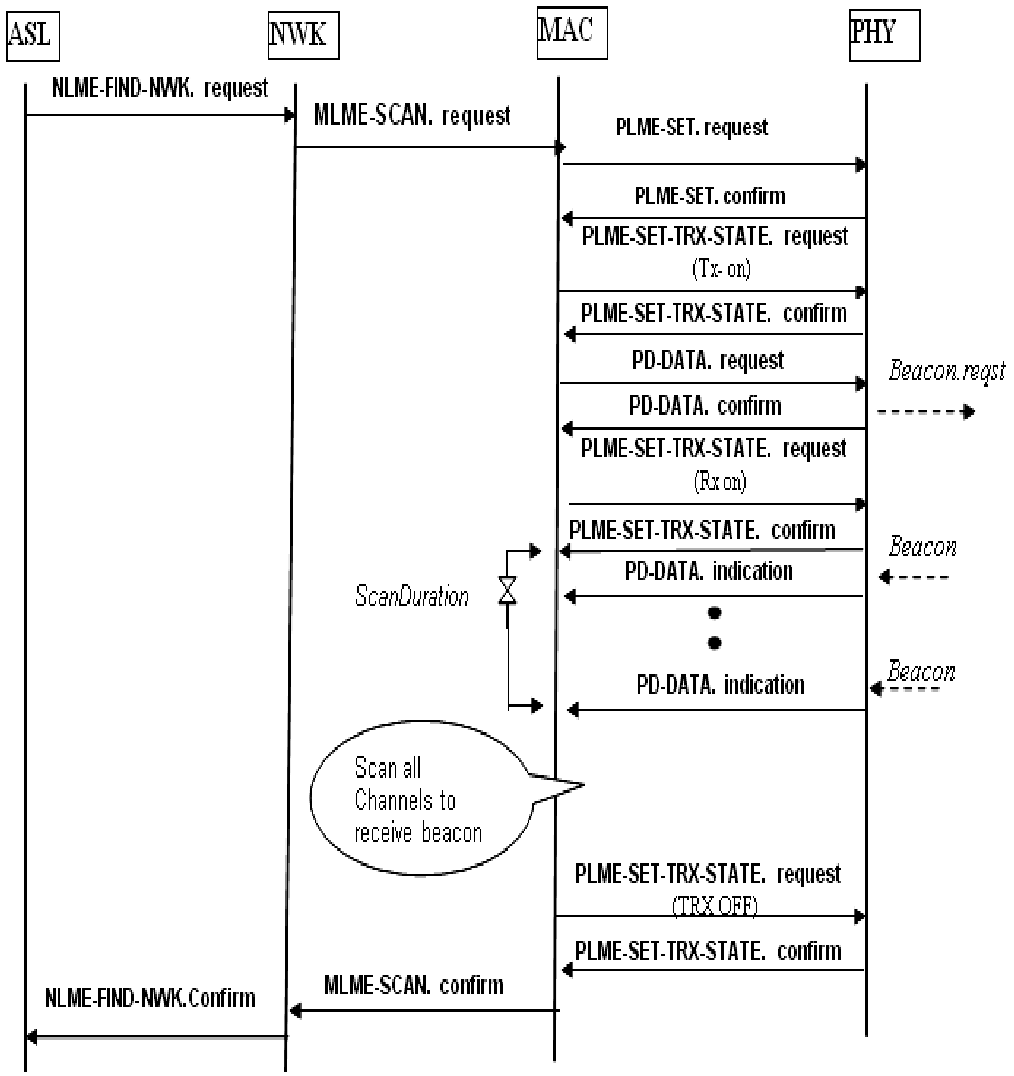


Figure.4 WSN scan primitive by the Mobile node.

5.2 Association with the Coordinator

The association process starts by selecting a channel from the scanned result list and forwarding its request to associate with that particular coordinator. As the coordinator gets the association request, it decides about the association of the requesting device to its network.

The association process is initiated by the application sub layer by sending the *NLME-JOIN-NWK.request,* to the selected coordinator using the lower layers. This primitive is generated by the ASL to the NWK layer requesting the unassociated device to join a network of the specific coordinator from the list of coordinators in its POS obtained from the scan channel process. During this request it indicates mainly its capability information to the coordinator.

NLME-JOIN-NWK.request

{

PANId, CoordAddrMode, CoordAddresss, CapabilityInformation,

}

The network layer instructs the MAC layer to construct the association request frame and to transmit as an association command to the coordinator by enabling the hardware. Thus the MAC layer sends the *MLME-ASSOCIATE.request* primitive requesting association with coordinator. It has following parameters:

MLME-ASSOCIATE.request

{

LogicalChannel,CoordAddrMode, CoordPANId, CoordAddress, CapabilityInformation

}

The coordinator on receiving the association request sends the association command to the requesting device with the Short address indicating its selection into its network. In this way a node joins the network of the coordinator of its choice.

After the formation of the network between the mobile node (MN) and the associated WSN coordinator, the newly associated MN sends its network information to all the network entities operating in the geographical area as broadcast information using its IEEE 802.15.4 link in the form of link independent frame. This makes the MIIS information server to know about all the newly joined networks to help in handover process. The main parameters passed by the node are as follows:

{

IEEE 802.15.4 ExtdAddress, ShortAddress, IEEE 802.11 LinkAddress, IEEE 802.16 LinkAddress, BeaconInfo, CapabilityInfo.

}

6. Mode of communication

The protocol stack of a WSN node which is meant for mobile activities consists of separate link features for IEEE 802.15.4, IEEE 802.11, IEEE 802.16, etc to provide seamless handover facility.

As soon the node is powered ON, the sensors communicate the gathered data to the destination using the 802.15.4 scan and association method. As soon as the node gets associated with the coordinator of the network (which is operating using the 15.4 link), node transmits the address and link details (current association address, extended address, 802.11 MAC address, 802.16 MAC address, capability information, etc) of all its other link technologies as a broadcast. This phase is needed to make the MIIS server to update its data base.

The node communicates with the coordinator as long as it is in physical range with the coordinator. If the coordinator moves out of range of the node's maximum physical coverage range (like the coordinator may be a laptop enabled with dot11 and 16, 3gpp link technologies) or vice versa (node moving away if its present with in a movable unit like a vehicle) the application will trigger the need of handover to the MIH using the suitable primitive (it may be initiated by the coordinator or the node). After this the MIH will take over the responsibility of providing continuous coverage to the requested party by performing inter technology handovers.

As per the present design, the MIH is configured to try to provide handover in the order starting with 802.11, 802.16, 3gpp, respectively. The figure 6 shows the primitives used for the handover to the new network:

Initially the MIH user of the MN requests the MIH to get the details of all the networks operating around the region using Get_nwk_info_request command. The MIH generates the command frame and transmits to the MIIS server using IEEE 802.11 interface.

{

Dest_Id, Src_Id, operational _freq, power_src, resp_time, link_addrs

}

When this request frame reaches the MIH of the server, it indicates to the MIH user of the server about the request. In response to this the MIIS server sends all the network details in the form of Get_nwk_response frame to the requesting MN.

{

Dest_id, interface_type, dist_info, link_addrs, capability_info,PoS_id,event_support, resourses_info

}

On receiving the network details of all the surrounding network interfaces, the MIH user of the MN selects

the best preferred network element based on the dist_info, PoS_id, event_suppoted, capability_info, resources_info parameters.

On deciding the future network entity to get connected, the MIH user of the MN sends Nwk_committ _request to the MIH of the selected network entity to accept the service request. This also indicates the selected network about the required resources, addresses, QoS requirements by the MN.

{ *Dst_ id, resources_info, link_addrs*

}

In response to this the MIH of the selected network sends the Nwk_committ_respose to the MIH of the MN indicating the status of the request. This re confirms the MN with its offered services.

{ *Dst_id, Link Addrs_list, Status, QoS_Supported, resources_list*

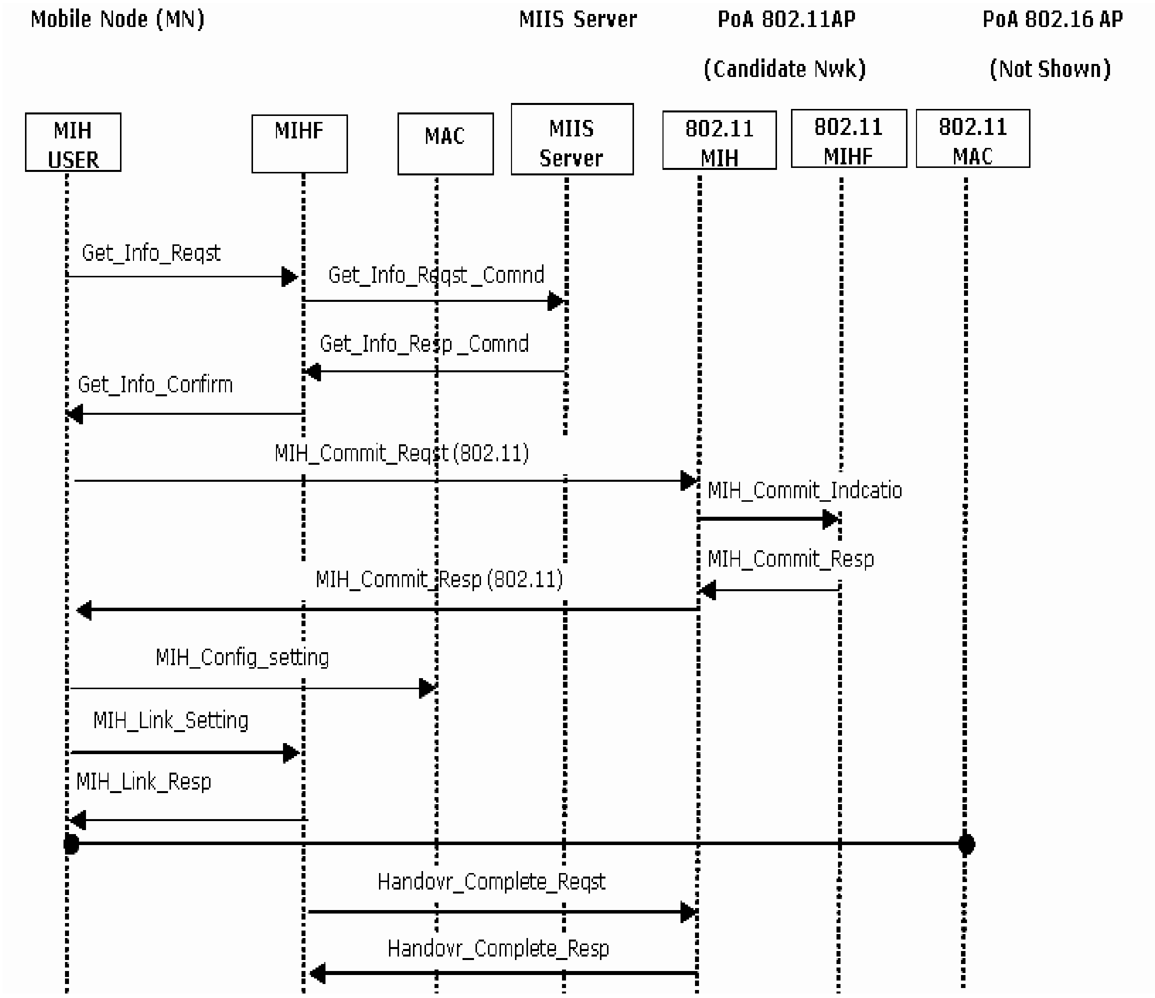
}

After the acceptance of the service request from the newly selected network, the MN has to configure its link interface to accept the service. So the MIH user function of the MN configures the MIHF to perform the lower layer settings as a result the MIHF indicates the MAC of the MN with the list of con figuration settings.

{ *Beacon_info, Link_infoBase, QoS_Supported*

}

Finally the handover of the MN to the new service point is confirmed by sending the completion request to the MIH of the PoS of the newly selected network by sending MN_HO_complete_request. On receiving this request, the MIH of the PoS confirms the possibility of handover by sending MN_HO_complete_response. After this the MN will be served by the 802.11 network



Fiure.5 MIH primitives for handover to 802.11 network

7. Conclusion

The proposed scheme of handover services in a WSN using IEEE 802.21MIH functions can perform satisfactorily to enable efficient data transfer. As soon as the formation of the network by the WSN nodes, as they broadcast their network information to all the elements within the network helps the MIIS server to know about all the link details of a particular wireless node; which enables the smooth handover. This scheme facilitates minimum delay during handover by pre establishing the link with an optimum IEEE 802.11 access point whenever it notices the poor link connectivity by the WSN interface.

The application layer assigns the preference for link connectivity in the order as IEEE 802.11, IEEE 802.16, 3G cellular network, thus the higher ordered network scan is done only if lower order networks are unavailable. This makes the handover process power conservative.

The proposed node architecture has internal partition to separate the WSN data from other interfaces. The network manager with in the network layer provides the required topology information to aid the candidate selection process.

The MIH primitives between the mobile node and 802.11/ 802.16 PoA has minimum redundancy in terms of parameters and thus supplied parameters are effective in forming the handover process smooth and efficient between heterogeneous interfaces.

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