

Enhancing Network Coverage using Handoff Techniques in Mobile Wireless Sensor Networks

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Abstract

Nowadays the world of communication is evolving very fast because of the advancements in the wireless technologies such as internet of things and wireless sensor networks. Initially these technologies were tested for a limited range, but because of their unlimited applications, the demand has increased which has led to research in the areas of extending the range of these networks. Each network has its own base station which works on a particular frequency. For smooth and uninterrupted movement of communicating nodes from one cell to another, there must be proper communication between the base station of the connecting cells. This is possible because of the Handover or Handoff techniques. When a node starts transmitting the data, it is connected to the parent node i.e. fixed base station and as it moves away from the parent node towards the destination its signal strength decreases but the strength from the neighbouring node increases. For the communication to survive the moving node connects to the neighbouring node while distancing from the parent node. This way there are number of hops for a node to reach the destination from the source. Thus as the node moves from one cell to another handover is done to provide continuous communication channel. This paper gives a brief introduction of the need of Handoff, factors causing the handoff process and various handoff techniques used in Wireless sensor networks.

Keywords: Wireless Sensor Networks, Mobility, Handoff, Roaming, Resource management

1. Introduction

Wireless sensor network is formed by thousands of sensor nodes which are covering a large area. Each node has its own microcontroller, memory, power source, transceiver, sensor or actuator. The coverage of the area is done by spreading the nodes over the region. To increase the capacity of the region the whole region is divided into small cells. Each cell has its own base station and limited number of nodes. Wireless sensor networks use the radio frequency channels as a physical medium for communication. When the data is transmitted from source to the destination, each data packet has the address of the destination on its frame header. If both (source and destination) are in the same cell then communication is easy but if the destination is in different cell that means the node is mobile to reach the destination. For this handoff is necessary to complete the communication. The Handoff can be explained with the example of ATC. The Handoff techniques are widely used in Air Traffic Control (ATC) for managing the air traffic. The primary purpose of ATC is to prevent collisions, organize the flow of air traffic by providing information without delay in the communication. If the received signal strength

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of the parent node is decreased and is not able to support the node in the neighbouring cell then the mobile node will start searching for the available networks. If the strength of the mobile node and the parent node reaches an optimum level (Δ) then the handoff process is triggered. The value of Δ is found from the expression:

$$\Delta = P_{r \text{ handoff}} - P_{r \text{ minimum usable}}$$

$P_{r \text{ handoff}}$ is the probability of signal strength at which handoff is made. $P_{r \text{ minimum usable}}$ is the minimum signal strength at which signal reception reduces to zero. So Δ cannot be too large or too small. If the value of Δ is large then it will cause unnecessary handoff and will be a burden over the neighbouring node. If the value of Δ is small enough then there is not enough time to complete the handoff and the signal terminates because of the weak signal. The value of Δ also depends on Environment, expected mobile node speeds and time required to perform handoff.

The critical feature of wireless sensor networks that allows the global communication is mobility management. Mobility management along-with the wireless sensor network communication enhances the application area to a large extent. Mobility means either the nodes or the event is movable. The basic purpose of introducing the mobility is to decrease the no. of hops to reach the destination, which actually reduces the power consumption. The wireless sensor networks are mostly deployed in locations which are hostile and inaccessible, hence it becomes difficult to maintain the nodes and replace the energy source for the sensor nodes. Therefore power consumption and efficient utilisation of available energy plays an important role in determining the life span of sensor nodes and thus sustenance of entire wireless sensor network. Mobility increases the communication between source and the destination. Mobility management enables the wireless networks to provide network coverage to all the nodes while moving from source to destination. When a node has to move from one cell to another to reach the destination, the process of mobility management takes place. Apart from power consumption in wireless sensor networks, mobility management of nodes deals with coverage, connectivity, handoff management and location management. Mobility management comprises of two major functions: (i) location management and (ii) Handoff management.

1.1. Location Management

Location management is the crucial parameter in wireless sensor networks. Many WSN applications require the location of the sensor node to be recognised. Various approaches are used to determine the location of the sensor nodes. In a network sensor nodes can be of two types, One whose location is known to the node using GPS called Beacon node and Second whose location is not known in the network called Unknown node. The location of the unknown node is estimated by using distance from the beacon node in its way. Once the location of the unknown node becomes known, then it act as a reference node for the other unknown nodes to find their location in the network. Thus Location management tracks the mobile devices and updates their current location in the system. It makes the node to be connected to the server so that sever can easily send its control signal to the mobile node.

1.2. Handoff Management

With the increase in demand of various wireless communication applications, no. of real time applications have emerged which are not confined to a particular region and are not restricted to specific networks. On the other hand these applications are spread across different regions having variety of networks. Mobile Telephony / Internet services being provided by different telecom operators and the roaming facility provided at the national and international level is one such example from daily life. While performing these applications in the wide area having different networks, wireless sensor network should follow the set of rules designed in a manner that the running applications should get the

continuous and uninterrupted signal. To meet these specifications of communication, efficient Handoff techniques are required to ensure the successful access of the multiple network services available in the path from source to destination. Handoff management is possible after the location management; the server sends the authentication credentials of the mobile node to the serving station which then provides its network to the mobile node for use. Handoff management actually decides when to do the handoff by considering the minimum threshold level.

1.3. Resource Management

Mostly the Wireless sensor networks are operated using independent power sources like batteries *etc.* these batteries have limited lifetime and many a times considering the cost factor, these are non-rechargeable. Such networks are meticulously designed to survive for a longer time and even for years to serve the mission. Such design time considerations include Energy Efficiency, Energy Harvesting, Network security and routing. Resource management is one important aspect which lays emphasis on efficient utilisation of resources such as battery life so as to maximize the network life time without any sort of disruption in the communication. Thus to meet this requirement of wireless sensor networks various resource management techniques are used such that the network will serve the region for a longer time without any discontinuation. Resource management is included in the every stage of communication it starts from transmitting end and these standards are followed until the signal reaches the destination. For the networks which are running no. of applications at a time, can use the concept of resource sharing. As part of resource sharing during a particular period of time, a single energy source is shared by all the applications rather than individual application using separate energy sources. During this time all other power sources are either switched off or are in sleep mode there by improving the network life time.

2. Need of Handoff

Handoff is necessary in any network to provide the continuous service to the mobile nodes so that there is continuous communication between the source and destination. Various scenarios in the internode communication which require Handoff are:

1. When a mobile node moves from one cell to the other where the parent node is not able to provide the signal then by the process of Handoff the mobile node gets signal from the neighbouring node.
2. When the parent node in the cell is interfered by any other node in the network, then for the security purpose the mobile node gets the service from the node in adjacent cell by the Handoff process.
3. When the source and destination are in the different cells called the Intercellular communication, then by using the Handoff process the successful communication is done by the mobile node.
4. When the source and destination are in the same cell called the intracellular communication. Nodes which are near to the parent node will get the strong signal, which may cause interference to the neighbouring nodes and the node which is away from the parent node will get the weak signal or the signal may get faded and the communication is not proper. Thus to reduce the near-far problem Handoff is done.

2.1. Factors Causing Handoff/Handover in the Wireless System

1. Signal strength: Received signal strength of the network should be optimum. It should not be too high or too low. If it is too high then it may cause interference in the

neighbouring nodes and if it is too low then it will degrade the signal quality. Thus the need of handoff arises.

2. Speed of the device: Speed of the device also affects the handoff. If the node is moving at a very high speed then the handoff is very fast and takes very less time. It may increase the load over the no. of hops which are already occupied by the nodes of its own cell.

3. Weaker signal from parent base station and strong signals from neighbouring base stations: If the condition arise that the node is getting weaker signal from the parent node and stronger signal from the neighbouring nodes then the node has to undergo handoff process.

4. Bit Error Rate: If the mobile node moves away from the parent node there is a decrease in the signal strength which reduces the signal quality and there may be a loss of signal. If we get the incorrect data which is not useful, it means there is a wastage of most limited resource of network *i.e.*, energy. Thus Handoff reduces loss of information by providing the strong signal from the other base station.

3. Types of Handoff

Handoff plays an important role in the wireless communication where the path from the source to destination is having multiple network services. Here either the source node or the sink node is movable and they have to follow the traffic rules made for the uninterrupted communication. To make this task more fruitful various type of Handoff techniques are used which are explained in this section:

3.1. Soft Handoff

It is also called make before break. In this type of Handoff the connections with the neighbouring node is first established and then the connection with the parent node is broken. This type of Handoff is considered better because in these chances of call break is less. In soft handoff the mobile node make connections with one or many neighbouring nodes before detaching itself from the parent node. The one which has the maximum signal strength, the mobile node is connected to that node otherwise it may get the average signal from all the connecting nodes to get the clear signal.

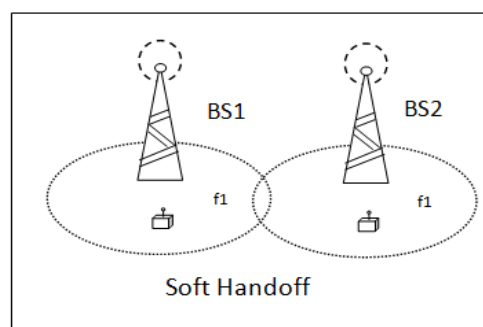


Figure 1. Soft Handoff

3.2. Hard Handoff

It is also called break before make. In this type of Handoff the connection with the parent node is first broken and then the connection with the neighbouring node is established. Here service provider has to provide continuous service to the nodes to provide continuous communication. This type of Handoff has more power consumption.

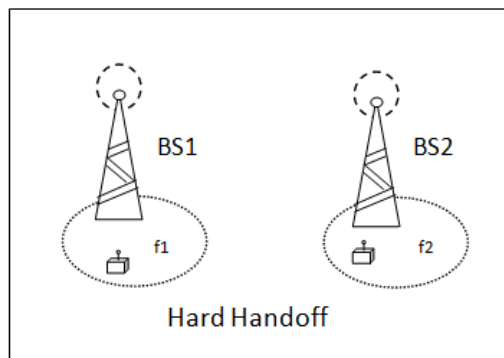


Figure 2. Hard Handoff

3.3. Softer Handoff

In this type of Handoff the mobile node changes its serving node within the same cell. In order to increase the service quality the cell is divided into sectors with their own service station but operating at the same frequency.

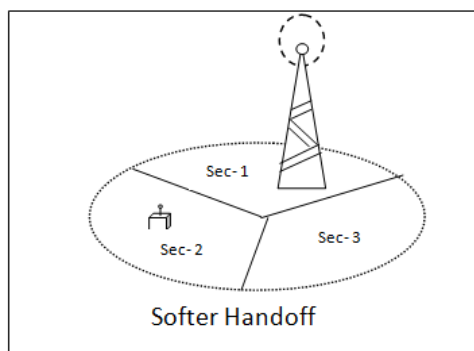


Figure 3. Softer Handoff

3.4. Inter-cellular Handoff:

In this type of Handoff the source and destination are in the different cells. When the mobile node is not in the same cell as of the parent, the signal strength from the parent node diminishes and to get the signal it has to depend on the nodes from neighbouring cells. In this situation, the handoff can be soft handoff if both are at same frequency or hard handoff if both cells are at different frequency.

3.5. Intra-cellular Handoff

In this type of Handoff the mobile node is in the same cell as of the parent node but not getting signal from it. Thus it will try to get the signal from other node within the cell. This type of Handoff is easy to establish as there is no need of authentication. In this the Handoff could be Softer Handoff as the node is getting signal from the different sector of the same cell.

3.6. Horizontal Handoff

In this type of Handoff the mobile node changes the access point while the technology remains the same. In this the mobile node may be in the same cell or neighbouring cell but that must have the same technology.

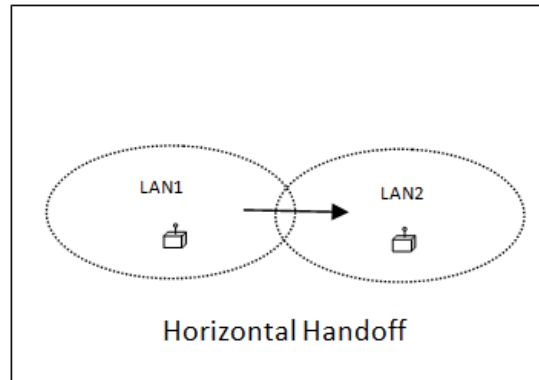


Figure 4. Horizontal Handoff

3.7. Vertical Handoff

In this type of Handoff the mobile node is compatible with more than one technologies viz. LAN, CELLULAR, GPRS *etc.* Vertical handoff allows a node to change the network with available compatible network. This technique makes the network completely transparent to the end user. Thus mobile node will use any of the technologies which are available in that particular cell to make the communication smooth.

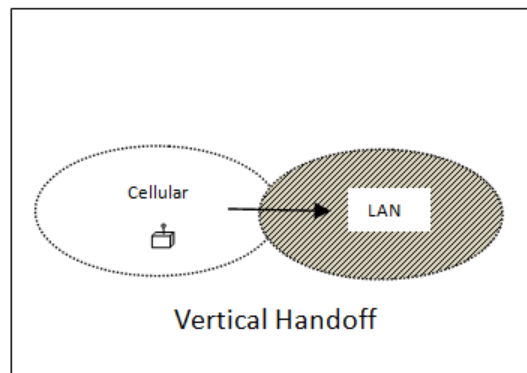


Figure 5. Vertical Handoff

4. Methods for Handoff Decision

4.1. Network Controlled Handoff (NCHO)

This type of Handoff is based on the measurement of signal strength at base station with respect to the number of base stations. In this type of handoff the decision is made by the base station regarding where to transmit the node in the network so as to make the signal transmission uninterrupted. This scenario is similar to the first generation analog systems such as AMPS, TACS, where the handoff is controlled by the network.

4.2. Mobile Assisted Handoff (MAHO)

In this type of handoff technique, the mobile station measures the signal strength of all the surrounding base stations and mobile node helps the base station to take decision in transferring the node to a new cell with stronger signal strength. In this process the handoff is the responsibility of the base station but the required parameters are provided by the mobile node. An example of such process can be seen in the second generation cellular systems such as GSM, where the handoff is controlled by mobile network.

4.3. Mobile Controlled Handoff (MCHO)

In this type of handoff each mobile station can perform the handoff on its own. Mobile station measures the signal strength from the surrounding base stations and also the interference level on all the channels and does the necessary handoff. This has improved the service quality as the reaction time has been reduced.

5. Handoff Prioritisation

Various communication systems handle the handoff process in two different ways. As per the first approach, they consider handoff as a new call. Handoff of this kind have the probability same as that of initiating a new communication. In such situation, the probability of ongoing communication to be continued in the other region is less. On the other hand, as per different approach, Handoff is given more priority than the initiation of new call. In this system it is considered that it will be more annoying to disrupt a communication in between and to initiate fresh call. Thus priority is given to the Handoff. This process is called Handoff Prioritisation. Prioritizing Handoffs is done in two ways:

Guard channel Concept: In Guard Channel Concept, the fixed no. of channels are allocated for handoffs. Thus if any node requires the service from the neighbouring cell then it will get the connection from the guard channels allocated for handoff. This reduces the handoff call dropping probability. This concept reduces the system capacity which is ignored because of its more advantages of providing guard channels and security.

Queuing Handoff requests: In Queuing Handoff request, the channels are not fixed for handoff and the channel is only available to the node if it is free. If all the moving nodes enter the neighbouring cell, then such nodes have to be in the queue if channel is not available for handoff. Channels are made available to the nodes on first come first serve basis, whenever the channel is free to access.

6. Practical Handoff Consideration

To increase the coverage handoff is done. For this the cell is divided in to small cells so as to accommodate large no. of nodes with more signal strength. These small cells are called micro-cells each having its own small sized antenna for signal. Small sized antenna consumes less power and thus saves power. Now if a node is moving from one cell to another then Handoff takes place. Practically we have two types of moving nodes. Those which are moving at slow speed and the others which are moving at high speed. Nodes which are moving at a slow speed will remain in a particular cell for certain time interval and will then gradually enter the neighbouring cell where handoff takes place. But the nodes which are moving at a high speed will remain in a particular cell for very short time and will move from one cell to another very quickly. They will remain in any particular cell for a very short time. To provide continuous and uninterrupted communication, the Handoff has to be provided by each cell which makes the channel busy and creates unnecessary burden over the channel as each cell has to provide channel to high speed nodes. Thus to overcome this situation a technique called Umbrella Cell Concept is introduced. In Umbrella Cell Concept a large sized antenna is installed which provides signal to the high speed nodes only. Thus it eliminates the burden of unnecessary handoff on the small sized antenna in the microcells which are now providing signal to the slow speed nodes only.

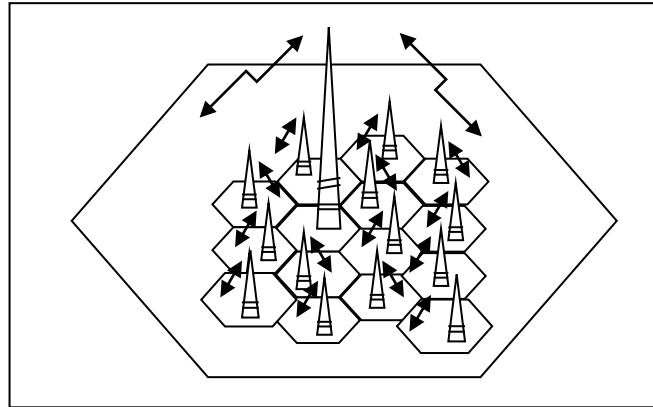


Figure 7. Umbrella Cell Concept

7. Handoff Failure

Handoff failure is the condition when the mobile node is moving away from the parent node in to the neighbouring cell and the communication is terminated. There are number of reasons that the handoff cannot takes place as if there is no channel available on the selected base station. There may be the probability that the target link may fail during the execution of the handoff. Handoff failure may take place if the target network denies the handoff due to the lack of resources. Handoff failure can take place because of the signal interference in which the power of the adjacent cell overpowers the current cell resulting in making the node insensitive. There is a possibility of handoff failure if a node enters a cell where all the channels are already occupied. Handoffs should be performed as infrequently as possible and should be successful whenever performed. This enables the sensor nodes to collect the data without any lag and with more accuracy. For this designer must set the optimum signal level for the handoffs to takes place. There should be certain monitoring device which actually calculates the signal strength of the node and determines whether change in signal strength is actual or momentary due to fading. For this the base station must check the signal level for a particular interval of time before a handoff is initiated. This period depends upon the speed of the node. If the speed of the node is fast then this time is less and vice-versa.

8. Conclusion

This paper gives an overview of Handoff process, need of Handoff, factors causing Handoff and various types of Handoff. It is important to do the Handoff in order to get the continuous communication. Handoff increases the network coverage by providing signal in the cell other than the parent cell. It enables the network to perform various sensing applications at distant locations without any hassles. Handoff process improves the system performance as this ensures optimum signal strength with in each cell in a large network. Measures should be taken so that the Handoffs should be fast and their effect on the Quality of service should be minimal. Handoff should provide low latency and minimal loss of information. Through this paper we have tried to provide an overview of various aspects of applying Handoff techniques on mobile Wireless Sensor Networks so as to ensure quality service without any disruption in communication and an enhanced network life time. In our further study we intend to discuss in more detail these aspects supported by simulations.

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