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Evaluation of Handover Protocols in Wireless ATM Networks

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Abstract: The extension of the ATM infrastructure with wireless access and mobility offer a great service advantages and high traffic performances. Allowing the Wireless ATM network in order to maintain the already QoS of ATM networks, some protocols of wireline architecture should be updated. The adaptation of the existing protocols to wireless requires integrating radio access functionalities and terminal mobility management. This last is an important factor in provisioning multimedia applications over wireless link. It adds the advantages of guarantying resource availability to the mobile terminals with QoS requirements. Mobility management needs several tasks as paging, location updating, routing, and handover. Particularly, handover has an important role to improve the services of WATM system. It is one of the major tasks that are used to support continuous transmission for a mobile terminal into different radio coverage areas. This research focuses on presenting an optimized handover algorithm. We propose a flexible architecture for implementing handover procedure based on intelligent decision strategy. This architecture is able to actively deploy different handover type. It can manage different network situations and allow mobile terminal to be connected to the most suitable base station.

Key words: Wireless ATM, handover protocols, QoS, performance evaluation

INTRODUCTION

This research introduces the characteristics of Wireless ATM network and its mobility extensions. WATM will be advantageous to support the seamless delivery of multimedia flows with high quality of service. In this way, WATM is intended to be a direct extension of the existing fixed ATM network. Mobility aspects in the WATM network and then the addition of some protocols to the physical medium cause a number of technical constraints which had to be solved. Mobility management is considered as one of the most important mobility support functions. It mainly refers to location management and handover protocols. Thus, maintaining QoS guarantees demands the addition of mobility support functions.

Particularly, this paper presents a solution, based on Handover protocol, for the mobility management of terminals in Wireless ATM networks. WATM is able to deploy different Handover types, which are intended to manage different network situations. For this purpose, several specific functionalities and algorithms are proposed. In our approach, improved backward and forward hard handover protocols were been developed for switching the MT active connections from one base station to another. This approach aimed at defining a solution with optimal method for applying handover in WATM environment. The emphasis was especially on deploying innovative process while maintaining Qos parameters. So, some details are explained particularly about signaling protocols. Present research is performed by validation phase.

WIRELESS ATM OVERVIEW

WATM prototype system: Wireless ATM network is currently under investigation in standards bodies. In 1996, the Wireless Working Group of the ATM Forum started to work on standards for the wireless ATM network. Since, it has specified various extensions of WATM protocols in order to cope with the user's mobility and wireless access (Wireless ATM Working Group, 1998). Furthermore, several companies like NEC (Raychaudhuri, 1997) and the Magic WAND ACTS project (Pronios and Dravopoulous, 1996; Ala-Laurila *et al*., 1998) started to develop and standardize WATM protocols. Then, the WATM technology is being introduced into the public and private telecommunication sectors (Wireless ATM Working Group, 1998). WATM prototype systems development allows extending the capabilities of traditional ATM technology transport over wireless links. Moreover, it provides mobile QoS

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requirements. Wireless ATM network will be then expected to support the same ATM service categories defined for fixed networks.

Several works have been done on the mobility support for WATM. Many examples satisfying these requirements are being developed as part of the ACTS Magic WAND project (Pronios and Dravopoulos, 1996). This approach offers the significant advantage of leading to simple and homogeneous network architecture. In this paper, we adopt the following architecture for our WATM model.

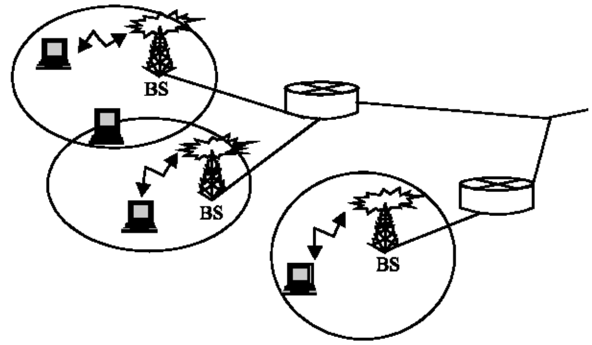

Fig. 1: WATM network architecture

WATM architecture: Figure 1 shows the WATM architecture maintaining wireless link between Mobile Terminal (MT) and Base Station (BS). The underlying WATM architecture and the used protocol stack of our study are derived from WAND's prototype implementation (Ala-Laurila *et al*., 1998). Typically the basic structure of WATM consists of three components types. Thus, the simulation mode of wireless architecture contains switches, Base Stations (BS) and Mobile Terminals (MT):

- MT (the end user equipment) is equipped with a radio adapter card interface. It roams in the geographical coverage area of BSs and exchange information with other MTs or fixed terminals. The MT protocol architecture introduces a Wireless MAC (WMAC) entity. This last helps to control the shared medium, to perform association or de-association with BSs, and to route ATM cells to the physical layer (and vice versa).
- BS represents the access point to the fixed network. It has mobility functionalities to cope with terminal displacement. Data transmission between the MT and the BS is achieved over wireless interface capabilities to manage WATM cells. The first base station role consists of adapting ATM cells to radio packets (and vice versa) and their emission/reception over the radio link. Second, the BS acts as the user network interface between the MTs and the ATM backbone network.
- Switch supports multiple connections classified in tow types. In one side, switch provides connections for BSs of the same group. In the other side, it represents a bridge for the wired backbone network. Each switch manages traffic between BSs according to the ATM standard transfer capabilities over high bandwidth links.

To maintain communication between MTs source and destination, several systems and links are used and many protocols and mechanisms are interacted. The following paragraph describes systems and protocols interaction and outlines meeting problems in this environment.

Protocols and systems interaction: This section provides a brief overview of the considered WATM network architecture. Details of protocol stacks of the various components as well as the functional entities needed to support them can be found in (Bhar *et al*., 2004; Ala-Laurila *et al*., 1998; Jiang, 1999). In the protocol stack, radio interface between BS and MT comprises the Radio Physical Layer (RPHY), the Radio Multiple Access Control Layer (RMAC) and the Radio Logical Link Control Layer (RLLC). It globally referred to as the Radio Access Layer (RAL). The end terminals require AAL Layer functions for end to end virtual connection. However, BSs and Switch support the ATM layer and can extract or insert handover protocol cells from/into the connection data flow (Bhar *et al*., 2004). SW, BSs and MTs communicate with each other using traffic Management protocols. These protocols are based on standard ATM control functions, such as ATM signaling, enhanced with wireless specific extensions. All BSs are connected to the ATM switch through a fixed ATM link. The BSs and MTs implement all radio dependent functionalities such as radio resource management, setup and release of wireless flows and handovers. The principal design objective was to maintain the compatibility between the wired and wireless ATM networks.

Each time a new connection between MT and BS is created, the radio resource manager is queried to check if there is enough radio capacity left. Authors control functionalities are required to satisfy performance of established connection. Placing most of the radio link control functions in one network entity needs high computing capacity requirements. However, the functional division between the network part (switch) and the radio access network (MT and BS) will decrease the complexity of the mobility management. This approach significantly improves the scalability of the system.

To support mobility functions at the switch, such as handover, specific functions will be attached to it. The mobility of users, cause problems that arise through wireless access. Approaches for the integration of wireless ATM protocols will be outlined in the following sections.

HANDOVER SPECIFICATIONS

In wireless environment, supporting hard delivery of QoS guarantees for multimedia applications is difficult. This is due to large scale mobility requirements, limited radio channel resources and fluctuating network conditions. In consequence, researchers have addressed a large attention to the areas of handoff criteria, connection rerouting, signaling extension, and QoS provision in Wireless ATM networks. Especially, handoff algorithms which are one of the important issues of mobility management are increasingly developed. Here we highlights the important issues to be considered for an efficient handover protocol design.

The handover procedure should allow users to move in wireless networks within a coverage area of a base station and may cross its boundary without dropping their communications. Since, the connections must be handed over new BS while QoS requirements must be satisfied. For this purpose, different steps of handover procedure are useful.

Handover basic steps: The handover process comprises three basic steps (Fig. 2): Measurement, decision and execution.

Handover measurement: It is a prediction phase allowing to detect the need for handover. The mobile terminal monitors traffic quality and controls signal strength indicators and error probability of the channel. It actualizes few parameters by making periodic measurements. The monitored parameters are treated at the MT for handover purposes.

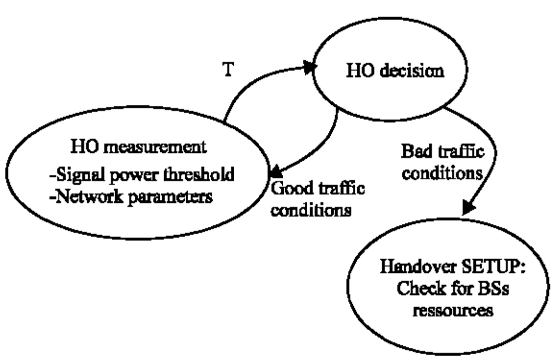

Fig. 2: Handover stages

Handover decision: If the signal characteristics drop below some thresholds, the MT sends Handover SETUP to a switch for searching new BS. If an appropriate radio channel and its associated base station are found, the switch informs MT to initiate handover process. The message contains connections references for all involved links, and a prioritized list of the possible radio ports. The decision to apply one type of handover is based on the information collected during measurement phase.

Handover execution: The handoff procedure establishes a new radio channel to the MT. Here, different handover types could be considered. A list of BSs candidate is proposed by the switch which decides about BS with optimal resources. One of the issues in handover relates to the possibility that the system may not be able to satisfy the desired level of QoS guarantees after a handover. The terminal, which moves from one BS to another, can request a new handover tentative to establish satisfied connection.

For the Handover execution two main handover types are proposed, backward and forward handover. We present in the following section, handover protocols based on inband signaling.

Handover protocols: We can identify two handover types: Backward and forward. This distinction refers to the BSs through which the handover signaling information will be exchanged. In backward handover, signaling messages are exchanged via the old BS (the BS the MT has been attached to during the recent past). In forward handover, the link with the old base station is suddenly lost. Thus, forcing the MT to seek connectivity through other, neighboring BSs.

Backward handover is performed by MT when it remains enough time to initiate handover via the old BS. When radio channel quality fades gracefully, MT could react promptly. It is often denoted brake-before-make. During a hard backward handover, when moving between two BSs, old BS connection is first released before establishing connection with a new BS.

Forward handover is run when a sudden radio link failure occurs and the MT couldn't transmit signaling information over the old BS. handover is often denoted make-before-brake. MT starts then a short procedure in which it attempts to recover the connection with a new BS. First, the MT establishes connection through a new BS. Second, data and control messages are transferred on the new connection before the old one is released. Forward handover is often denoted make-before-brake.

In addition to these main handover categories, several combinations or minor deviations of these may exist. The handover scheme trends consist of ensuring minimum data loss, when MT moves from one BS coverage area to another. Handover mechanism should switch the MT connectivity at optimal time over a suitable BS.

HANDOVER STRATEGIES CHALLENGES

Several proposals of handover schemes have been proposed for WATM network. Specially, different architectures give open issues for research. In literature, proposals allow to classify issues according to some related parameters, unexpected network situations and suitable implementation methodology. In consequence, proposals evaluation depends closely on the considered hypothesis.

Thus, proposed handoff schemes can be classified according to how these are processed. Many researches justify the benefit to use different handover schemes for different types of traffic to preserve the requirements of each traffic situation. This idea is explained and proposed (Marsan *et al*., 2001a; Jiang, 1999; Krieger and Savoric, 1999; Savoric *et al*., 2000; Dimitrios *et al*., 2002). An important handover issue, considered in these proposals, concerns handoff initiation decision.

Handover initiation phase: Several researches choose to initiate handover mechanism by MT to decrease complexity of switch functionalities. User must take intelligent handover decisions, in order to prevent different network shortcomings related to handover procedure. In this way (Pitsillides *et al*., 2001; Savoric *et al*., 2000) assume that the handover is started by MT which is free to move from one BS to another. Handover (Yuan *et al*., 1996) is initiated by the current base station, which controls the signal power received from MT. Current BS select between the neighbor base stations the best candidate. For other scheme, handover can be initiated by the MT, the network or a combination of both. This last approach is considered, in this paper, to improve the handover process performances. In fact, we have considered that handover mechanism is initiated by MT because this technique requires less dialogue traffic, so it reduces the overall handover time and signaling load. Switch has a great role to give optimal BSs candidates list to MT.

Different metrics are used to initiate handover such as signal strength, distance, signal to noise ratio, bit error rate, traffic load, word error indicator, quality indicator, and some combination of these. These metrics can be measured and processed on the network node or on the MT. For other schemes, handover is initiated when the signal power, received from the target base station, decreases under an acceptable threshold. However, this criterion, exploiting only wireless signal strength, is insufficient for some situations. In this way, other proposals algorithms consider multiple traffic parameters. This approach presents the inconvenient of handover decision complexity to consider these multiple criteria. There are also several handoff decision algorithms using artificial intelligence tools, like fuzzy logic systems and neural networks (Maturino-Lozoya *et al*., 2000), to process collected metrics. hese algorithms are complex to implement.

Signaling strategies: Handoff signaling enables wireless terminals to move seamlessly between BSs while maintaining connections with their negotiated QoS. Bad handovers signaling lead to degraded power quality. They also have a deep impact on the transport functions and band occupancy. (Chiasserini and Cigno, 2002) presents a scheme for handover provisioning in Wireless ATM networks based on in-band signaling. Signaling information is carried using fixed cell size equal to data cell. Handover signaling message integrates control channel for some signaling functions. Therefore, in proposal (Marsan *et al*., 2001b), the handover protocol is entirely based on dedicated cells that are transmitted with the data flow. The dedicated cells, termed Mobility Enhancement Signaling (MES) cells, are Resource Management (RM) cells similar to those used in the Available Bit Rate (ABR) ATM transfer capabilities. We propose to use the in-band signaling technique as explained in (Chiasserini and Cigno, 2002; Marsan *et al*., 2001a). This choice has significant advantages such as modification requests avoidance in WATM signaling functions. It also guarantees in-sequence cell delivery over the connection during handover procedure.

Handover procedure: Handover procedure allows guarantee the terminal connection reestablishment when it moves between areas covered by different base stations. It is useful to satisfy user radio link transfer without interrupting a connection. Then, Network gives to users freedom of motion beyond a limited wireless coverage area. Handover procedure should guarantee an in-sequence cells delivery to terminals, with minimum cell loss rate and short delay to satisfy a desired QoS.

Handover setup: During handover setup, the switch sends, to the MT, a BSs list prioritized by the signal power of each one. The MT selects then the suitable base station. Otherwise, communication efforts with the current BS will be wasted. The BS list increases probability for handover successful. However, it may cause additional delay. So, the Mobile Terminal initiates the handover setup when network parameters indicate radio link quality degradation. The MT sends then, via the old base station to the switch, a Handover Setup Request message notifying the intention to change BS. As the switch receives the request message it starts to establish connections to new base stations. The switch broadcast an equivalent setup request message to new base stations in order to check their network capabilities. Candidate BSs, which could support the new connection, respond. Then they are identified by their handover response messages sent to the switch. This last makes its final decision to select BS and RP after verifying that the necessary network resources are available. Finally, it notifies the mobile terminal about identities of the BSs involved over old BS and screen out unsuitable candidate BSs. Immediately after receiving these informations, the MT begin Handover procedure.

Handover operations: A successful handover procedure will contain the following phases. The mobile terminal begins by sending a HandOver Request message (HOR). This last is sent over old or new BS whether backward or forward Handover is decided respectively. Upon receiving the message, the switch identifies the network parameters, and then forwards to the terminal a handover decision. While waiting for the network reply, the MT continues to transmit (receive) cells over the current connection path (Marsan *et al*., 2001b). When receiving the HandOver Confirm (HOC), the new BS reserves the necessary resources and confirms to the switch that it is ready. The switch sends a forward message to old BS in order to start sending buffered downlink cells to new one.

In our model, resource allocation is done after the switch decision. In fact, it is not necessary to reserve resources in each BS for the connection when they receive the HOR message because only one BS will be finally chosen. Switch needs to send only one Handover message to the selected BS for resources allocation. This solution reduces the message processing time of other BSs. The efficiency of the whole network will thus be improved. However, for (Jiang, 1999) allocation resource in new BS is made at the end of handover procedure setup.

A promising approach to meet QoS requirements is based on the storage of data cells in the selected BS buffer, while the connection is being reestablished. Indeed, until the new wireless link is created, cells cannot be transmitted between the MT and the BSs. During this time, it may be necessary to transfer stored data cells from old BS to new one. The reason is that MT is disconnected from current BS and not yet connected to the selected one. The old BS sends a handover confirmation when their buffers are being emptied. Then the switch notifies BSs that the handover is in final progress step. It informs old BS to disconnect from the MT by sending the HandOver End message. New BS is also informed to establish a new wireless link with the MT.

There are different choices with which MT should establish the new connection. Data is sent simultaneously to MT from old and new BS (Vidal *et al*., 1999). This approach minimizes buffer occupancy but it needs more resources. However, (Krieger and Savoric, 1999) MT can wait for current BS to send all buffered cells to new one. This is a good choice for connections without critical timing requirements. However, when there is no end buffering confirm message, data loss can appear. Thus, we think that it is important to indicate the number of cell buffered in the old BS. Else, a cell transfer in old BS to new one may be not guaranteed. Here we assume that MT can wait for current BS to send all buffered cells. Old BS transmits to the switch an end buffering information allowing the new BS to start transmission so that the cell order is maintained. However, (Jiang, 1999) considers that MT should establish connection with new BS before disconnecting from the old one. In this way, old BS can be asked for another handover if MT cannot establish the new radio link, thus ensuring a loss less handover. In a successful Handover case, MT and new BS exchange cells via the newly established wireless link. Otherwise, the switch sends a Handover Denied message (HOD) and the handover procedure can be re-initiated by the Terminal.

In this research, hard backward and forward handover will be supported by WATM. Backward handover is usually used as first solution. When the radio link is suddenly degraded, the MT will be notified by the signal level, and a forward handover procedure will be initiated to recover the connection. In this case, the terminal interrupts the old connection and tries to connect to a new BS. Generally, handover protocols proposition is based on while retaining cell loss QoS guarantees, handover procedure delay and reliabilities of wireless channel. This technique enables flexibility and robustness in handover control systems. Otherwise the handoff can be slow and inefficient. Figure 3 shows the proposed handover solution. It reduces, in one hand, the number of control signals required for handoff. In the other hand, it optimizes the buffered information sizes during handoff, in order to significantly improve the radio link transmission accuracy.

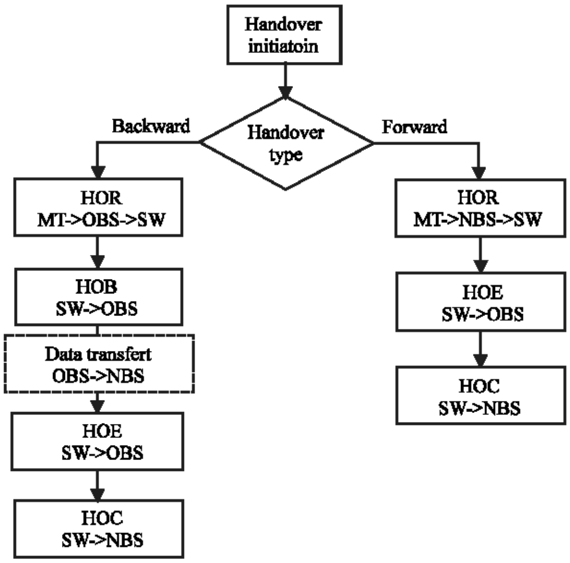

Fig. 3: Handover protocols

PROPOSAL STRATEGIES

The handover algorithm integration, in wireless ATM, presents several technical challenges that need to be resolved. This paper is focused on the handover decision making process which satisfies the objectives mentioned above. This process may lead to decide whether handover is necessary and whether additional adaptation needs to be applied. Objectives include satisfying the user's devices preferability, supporting important bandwidth for their respective applications (while minimizing packet loss, delay and jitter) and avoiding bandwidth fluctuations which may affect the applications. To define our architecture while maintaining optimal resources to the mobile terminal, the following approaches are adopted:

- The MT initiates Handover when the signal drops below than a threshold. WATM network participates to trigger handover by informing MT about traffic management parameters. The mobile terminal announces the beginning of its handover a short period before the real handoff procedure occurs (Bhar *et al.*, 2004).
- During handover, control messages are exchanged between different components of the WATM network. They are required to handle functions as begin, confirm, and end of the connection with network nodes. They inform nodes also about handover protocols type and QoS negotiation.
- In our scenario, handover signaling messages are derived by resource management cells. The goal is to efficiently collect and manage the network information. To make the appropriate decision, suitable algorithms are implemented for interpreting the data delivered by the context management framework.
- The optimal BS candidate for the handover is decided by network. The preselection is based on user defined policies and network constraints, so that the number of possible candidate networks can be greatly reduced.
- The mobile terminal supports two alternative handover mechanisms: backward and forward handover. The handover type depends on the radio link quality.
- During handover, we assume that two connections (the old one and the new one) could coexist but only one of them is active.

OBSERVATIONS AND RESULTS

Observations: The proposed algorithm handles intra-handovers where the old and the new BS are connected to the same ATM switch. Inter-handovers, where the old and the new BSs are connected to different ATM switches, can easily be considered with the developed architecture. Handover protocol behavior supports different network situations. Signalling handover message and the coexistence of wired and wireless connections in the same environment present a key issue. Wired connections speed is faster than wireless connections. Therefore this difference in transmission rate requires high buffer occupancy in BSs. Specially in hard handover, the intermediate (old) BS should have capabilities for buffering data cells, destined to the MT, and transferring them to the new BS in order to preserve information sequence.

This work lies in the development, implementation and discussion of handover procedures. It shows performance analysis of Handover algorithms based on some hypothesis. In fact, system parameters are fixed to reduce the number of validation experiments. Parameter values used for validation are selected according to typical cases, rather than providing an exhaustive evaluation of all potential system scenarios. The main objective illustrates and validates an innovative contribution for new intelligent handover algorithm. Performance evaluation is given by simulation in the following section.

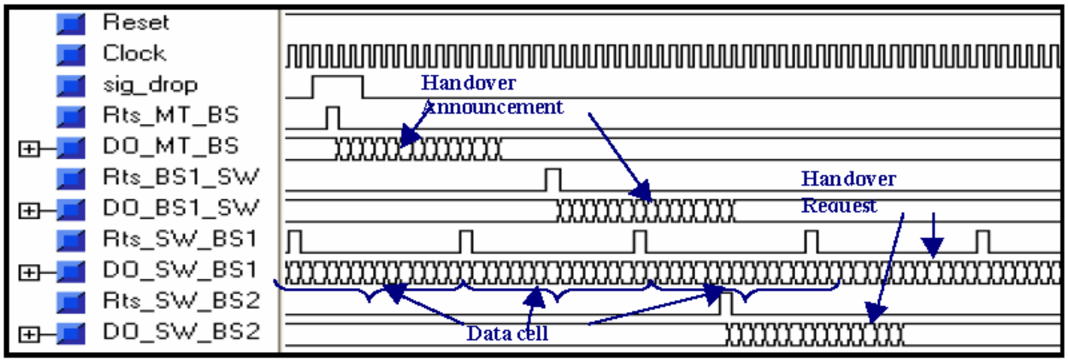

Fig. 4: Initiation of Handover procedure

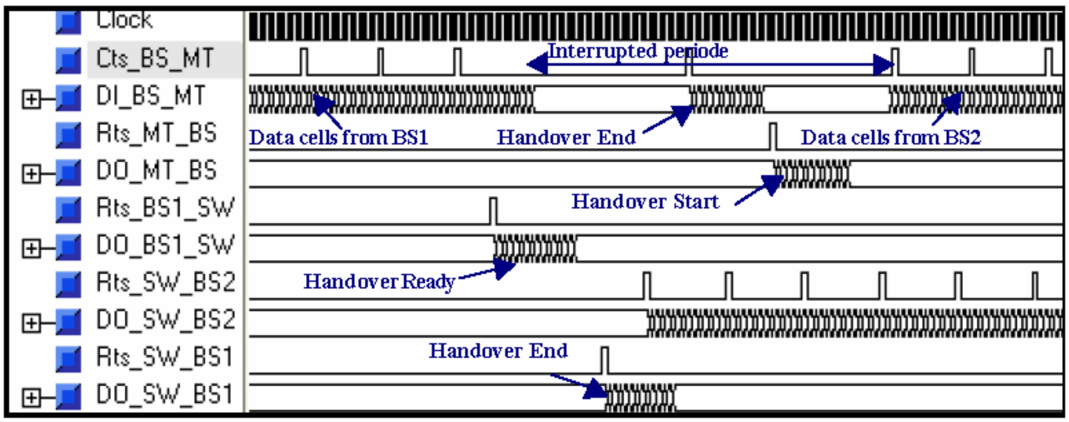

Fig. 5: Handoff from BS1 to BS2

Simulation results: Our approach of handover has been transposed on a concise description which supports different Wireless ATM simulation scenarios. The efficiency of this description for several network situations evaluates the Handover algorithm performances. Handover algorithm has been implemented in an FPGA environment based on simulation and synthesis tools. This algorithm has been integrated, in three parts, on the base station, the MT and the switch according to their specific tasks. Simulation environment contains two Base Stations (BS1, BS2), one Mobile Terminal (MT) and one switch (SW). This architecture is based on two channels that could be established from the switch to the MT. Our proposed handover model is extensible for multi-channel architecture based on multi-hierarchical level (MTs, BSs, SWs).

Figure 4 shows the initialization of Handover procedure. When signal power drop is detected, the MT sets the sig_drop to 1. At this event, the MT transmits to the current BS (here BS1) a Handover announcement. This last will be transmitted to the switch, which will activate BSs resources request. The switch remains waiting to collect network parameters of each BS. It sends, thereafter, a Handover Start to the terminal for Handover execution beginning. In Fig. 4 and 5 multiple Handover messages are omitted, we give here an overview of critical sequences of Handover process.

Figure 5 shows a network scenario that we consider for performance evaluation of handover procedures. It presents a BS switching through which a terminal receives data. The BS converts cell data in order to adapt ATM and WATM cell formats. Data cell transmission is initialized by Request To Send (RTS) signal. Data are transmitted over (32 bits) port accompanied with four control bits. A control bit is set to 1 to indicate delimiter and special characters and 0 to indicate data bits.

The table below shows synthesis result obtained by synopsis tool:

	MT	BS	SW
Number of ports	154	224	224
Number of cells	6783	16208	15350
Total area (mm^2)	3.706	8.192	7.567

Finally, results obtained from handover protocol implementation reveal that implementing mechanism is feasible, as it maintains the QoS characteristics and fails at higher data rates. Since, it is essential to evaluate the handover protocol in an environment with multiple mobile terminals. It is also important to apply routing algorithm to provide a robust handover mechanism.

CONCLUSION

This study presents a handover protocol for wireless ATM networks, using two types of Handover process. Experimental algorithms have been specifically designed to evaluate the impact of handover control mechanisms for WATM. The handover procedure is performed to ensure sequence integrity and to guarantee cells loss free delivery during this transition process.

Performance results reported in the literature are mostly obtained via simulation or experimental prototyping. Because analytical models (Marsan *et al.,* 2001a) that estimate handover protocols performances and buffering schemes in WATM networks are not available. They are based on quite simplistic approximations that lead to partial results. Analytical models are usually considered as complex especially for implementation. However, estimated condition can lead to inefficiency in some network situations. They do not completely characterize the effectiveness of the handover protocols and buffering schemes. So, we claim that the implementation in a software/hardware simulated environment has not been considered thoroughly in the literature. They always use analytical approach and software validation. Thus, our work elaborated on this design environment is considered an original contribution.

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