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Poster Paper

Controlling the Handover Mechanism in Wireless Mobile Nodes using Game Theory

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Abstract: This paper proposes a novel network selection mechanism as an extension to the FMIPv6 [2] protocol, which improves handover latency in the MIPv6 [1] in the case where the Mobile Nodes (MN) have a single wireless interface with multiple Care-of-Addresses (CoA's). Moreover, this paper proposes a novel interface/network selection mechanism, which is an extension to the MFMIPv6 [5], which work when the mobile node has more than one wireless interface. Generally, the previous access router (PAR) in the FMIPv6 protocol forwards all the arrived packets to the new access router (NAR) by setting up a tunnel to it in order to prevent packet losses incurred by latency during handover procedure. However, there is no protocol which offers the user and/or the application to dynamically choose the right NAR (i.e. the one offers a better service). What's more, one of the main objectives of the next generation networks will be heterogeneity in the wireless access environment in which a mobile terminal will be able to connect to multiple radio networks simultaneously. For these reasons, network selection and efficient load balancing mechanisms among different networks will be required to achieve high-speed connectivity with seamless mobility. To this end; Game Theory [3], naturally becomes a useful and powerful tool to research this kind of problems. Game theory is a mathematical tool developed to understand competitive situations in which rational decision makers interact to achieve their objectives. The mechanism improves the handover latency, the user ability to choose the right interface/network and controls when to force the MN to make the handover.

Keywords: FMIPv6, MFMIPv6, Game Theory, interface selection, handover latency.

1. Introduction

Nowadays wireless technologies are widely used in IPv6 [1] communication. In addition to sharp increase of mobile terminals, various kinds of wireless technologies are available for the mobile nodes. Therefore, many mobile nodes begin to have multiple wireless interfaces and every user wants to use them simultaneously to reinforce connectivity to the Internet. Selection of the most efficient and suitable access network to meet a specific application's Quality of Service (QoS) requirements has thus recently become a significant topic, the actual focus of which is maximizing the QoS experienced by the user. The main concept is that users will rely on intelligent network selection decision strategies to aid them in optimal network selection. FMIPv6 [2] already offers some rudimentary handover features. For instance, a MN may send a Binding Update to its PAR. This causes the PAR to redirect packets towards the new CoA of the MN. In the present context, while the MN moves around a certain area, it keeps checking the around access routers (AR), once it receives that there is an AR around it, it will start the handover procedure between the PAR and the NAR. Yet, there is no way for the user and/or the application to force the MN not to make the handover, in order to stay with the AR that offers a better service.

On the other hand, Game Theory [3] is a set of tools developed to model interactions between agents with conflicting interests, and is thus well-suited to address some problems in communications systems, which might be related to interface and/or network selection mechanisms. Game theory skills can be easily adapted for use in radio resource management mechanisms in a heterogeneous environment. Accordingly, this paper presents a mechanism for combining interface and/or network selection mechanisms and game theory, in such a way that the user have the ability to dynamically control which network to connect to while moving around different access points.

2. MIPv6, FMIPv6 and MFMIPv6 Protocols

Recently, various kinds of wireless technologies are available for the mobile nodes. Mobile IPv6 [1] describes the protocol operations for a mobile node to maintain connectivity to the Internet during its handover from one access router to another. As mentioned earlier that; the solution of keeping ongoing connectivity on the move is by using several interfaces and use them simultaneously. However, the basic Mobile IPv6 protocol [1] cannot support the simultaneous usage of multiple interfaces, because the MIPv6 does not allow a mobile node to register multiple CoA's corresponding to multiple attachments of several interfaces. The reason why everybody is looking to add multiple wireless technologies to a mobile node is clearly because they can be used for various purposes. For example, an interface can be used as backup to recover from possible loss of Internet connectivity of another interface. Moreover, two or more interfaces can be used simultaneously to increase the aggregate bandwidth, or load sharing of different applications. Recently, the multiple CoA registration protocol [4] extends the Mobile IPv6 protocol with an option called "Binding Unique Identifier (BID) sub option" to associate multiple CoA's with one home address. Although the Mobile IPv6 protocol describes a procedure to maintain connectivity to the Internet during handover, the involved handover latency may degrade quality of the Internet applications which are delay-sensitive or throughput-sensitive. As a result, the fast handover Mobile IPv6 (FMIPv6) protocol [2] has been proposed to reduce the handover latency. Generally, FMIPv6 tries to reduce the movement detection latency and the new CoA configuration latency by processing the handover signalling in advance.
The basic idea behind the FMIPv6 is that; the Present Access Router (PAR) forwards arriving packets for the mobile node to the new access router (NAR) by setting up a tunnel to the NAR in order to prevent packet losses incurred by handover latency during handover procedure. For the same reason, it is necessary for the multiple interface Mobile IPv6 [1] protocol to adopt a fast handover procedure to enhance its handover performance by reducing handover latency and packet losses. More details about the FMIPv6 can be found in [2].

Generally speaking, the FMIPv6 Protocol [2] works as follows; essentially the handover procedure starts when a MN sends an RtSolPr (Router Solicitation for Proxy, which is a message from the MN to the PAR requesting information for a potential handover [2]) message to its AR through a handover-interface to resolve one or more Access Point Identifiers to subnet-specific information. In response, the AR sends a PrRtAdv (Proxy Router Advertisement, which is a message from the PAR to the MN that provides information about neighbouring link facilitating expedited movement detection [2]) message containing one or more access point ID and information. The MN may send an RtSolPr as a response to some link-specific event (a "trigger") or after performing router discovery. However, prior to sending RtSolPr, the MN should have discovered available APs by link-specific methods such as AP scanning procedure in IEEE 802.11 wireless

LAN. The RtSolPr and PrRtAdv messages do not establish any state at the access router [1]. More details about the packet formats can be found [2].

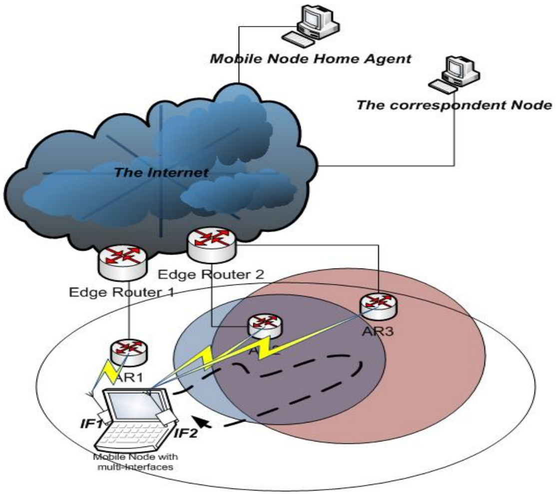

Figure 1: MN with multiple interfaces.

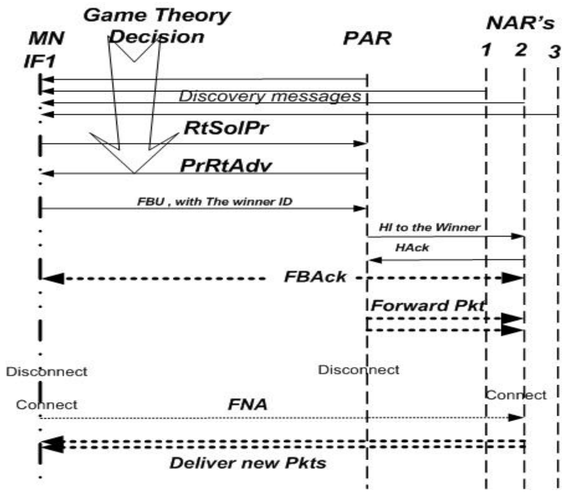

Figure 2: FMIPv6 handover procedure with Game.

With the information provided in the PrRtAdv message, the MN formulates a prospective NCoA (New CoA) and sends an FBU (Fast Binding Update) message. For a single interface FMIPv6, the main purpose of the FBU is to inform PAR of binding PCoA (Previous CoA) to NCoA, so that arriving packets can be tunnelled to the new location of the MN. However, so far the FMIPv6 [2] doesn't offer the MN any ability to choose the right AR at the right time. The proposed extension, presented by this paper shown in figure 2, works as follows; as the MN receives the PrRtAdv messages from the PAR as it moves around, the game controller will be responsible of extracting the QoS parameters of them. The network interface receives all the packets at the node channel from other nodes or access points, each transmitted packets is stamped by the interface with the meta-data related to the transmitting interface [10]. The meta-data in the packet header includes information such as, transmitting power, wavelength, available QoS, security authentication etc., for the transmitted packets. The Game Controller is to be inserted at the network interface in the MN, the game controller is going to extract the packet header in the same way used in the propagation model, where the meta-data in the packet header is used by the propagation model to determine if the packet has the minimum power to be received and/or captured and/or detected. When the MN sends and receives the RtSolPr message and PrRtAdv message, the format of these messages described in details in [1], the game controller will know the source of each PrRtAdv message and extract the QoS information from it and by using the mechanism explained in section "III", the MN will decide which one is the best AR to go with. The MN will send the address of the NAR to the PAR by the FBU message.

Thus, in the literature [5] an extension to a multi-interface fast handover Mobile IPv6 (MFMIPv6) procedure have been proposed, which can indicate a specific tunnelling destination except the NAR, for example, one of the other interfaces (or CoA's) in the same mobile node. Then the severe reordering during handover procedure can be mitigated and the handover performance is enhanced. One of the main advantages of the MFMIPv6 protocol is that; the throughput of a TCP flow would increase by avoiding the unnecessary congestion control. Moreover, the named mechanism can improve the handover signalling performance because data traffic is redirected to another interface during handover signalling. After the successful handover of the corresponding interface, the redirected traffic flow is restored to direct to the NAR and finally to the original interface.

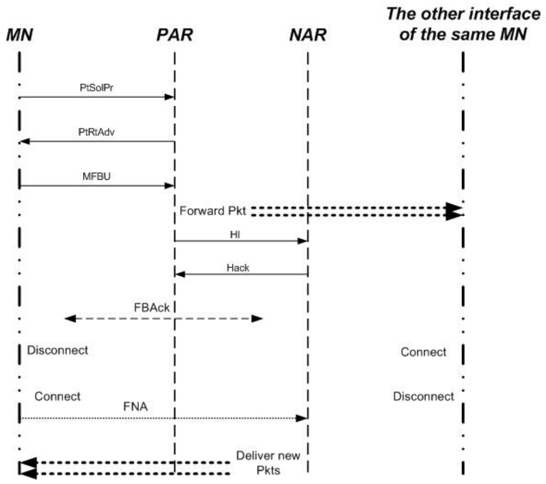

Figure 3: MFMIPv6 handover procedure.

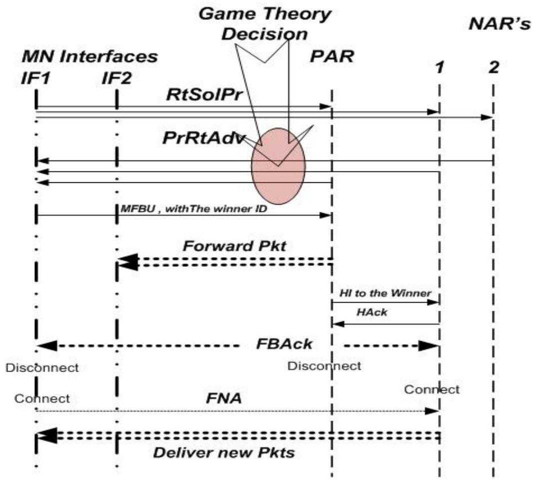

Figure 4: MFMIPv6 handover procedure with Game Theory.

Generally speaking, the MFMIPv6 Protocol [5] works as follows; essentially the handover procedure starts when a mobile node (MN) sends a RtSolPr (Router Solicitation for Proxy) message to its access router (AR) through a handover-interface (e.g., interface 2 connected to AR2 and AR3 in Figure 1) to resolve one or more Access Point Identifiers to subnet-specific information. In response, the AR (e.g., AR2 or AR3 in Figure 1) sends a PrRtAdv (Proxy Router Advertisement) message containing one or more access point ID and information. The MN may send an RtSolPr as a response to some link-specific event (a "trigger") or after performing router discovery. However, prior to sending RtSolPr, the MN should have discovered available APs by link-specific methods such as AP scanning procedure in IEEE 802.11 wireless LAN. The RtSolPr and PrRtAdv messages do not establish any state at the access router [5]. Their packet formats are defined in FMIPv6 [2]. With information provided in the PrRtAdv message, the MN formulates a prospective NCoA (New CoA) and sends an FBU (Fast Binding Update) message. For a single interface FMIPv6, the main purpose of the FBU is to inform PAR of binding PCoA (Previous CoA) to NCoA, so that arriving packets can be tunnelled to the new location of the MN. The overall handover procedure of MFMIPv6 is illustrated in figure 2. More details of how the MFFMIPv6 handover procedure works, the format of the MFBU message, how to tunnel the traffic to the NAR, and its advantages and disadvantages against the FMIPv6 are explained in more details in [5].

3. Explanation of Game Theory in Wireless Communications

Due to the complexity of mobility and the traffic models in mobile networks, together with the dynamic topology and the changeability of link quality that characterize the wireless and mobile networks, the application of mathematical analysis to those networks has met with limited success [6]. The reason that makes game theory mostly attractive to analyze the performance of all kind of problems related to the wireless networks is; it has the ability to model individual, independent decision makers whose actions potentially affect all other decision makers. Furthermore, game theory is a field of applied mathematics that describes and analyzes interactive decision situations. It consists of a set of analytical tools that predict the outcome of complex interactions among rational entities, where rationality demands a strict adherence to a strategy based on perceived or measured results [3].

Game theory studies strategic interaction in competitive and cooperative environments. Half a century old, it has already revolutionized economics, and is spreading rapidly to a wide variety of fields. In the early to mid 1990's, game theory was applied to networking problems including flow control, congestion control, routing and pricing of Internet services [6]. Non-cooperative and Cooperative games were introduced by John Nash (in papers between 1950- 1953), his most contribution was his existence proof of an equilibrium state in non-cooperative games, the Nash equilibrium [3]. More recently, there has been growing interest in adopting game-theoretic methods to model today's leading communications and networking issues, including power control and resource sharing in wireless and peer-to-peer networks. Moreover, leading computer scientists are often invited to speak at major game theory conferences, such as the World Congress on Game Theory 2000, 2004 and 2008 [7]. So far, evidence of previous researches shows that game theory may be an appropriate tool to solve some problems in communications systems; this section presents some of the most important concepts of game theory and some particular concepts which will be important in our proposal. Normally, any game has three components: a set of players, a set of possible actions for each player, and a set of utility functions mapping action profiles into the real numbers. In this paper, the set of players are denoted as $\boldsymbol{I}$, where $\boldsymbol{I}$ is finite with, $I = \{1, 2, 3, \dots, I\}$. For each player $\boldsymbol{i} \in \mathbf{I}$ is denoted by Ai the set of possible actions that player i can take, and A, which is denoted as the space of all action profiles is equal to:

$$\boldsymbol{A} = \boldsymbol{A1} \times \boldsymbol{A2} \times \boldsymbol{A3} \times \dots \times \boldsymbol{AI} \quad (1)$$

Finally, for each $\boldsymbol{i} \in \mathbf{I}$, we have $\boldsymbol{U_i}: \boldsymbol{A} \rightarrow \boldsymbol{R}$, which denotes $\boldsymbol{i}$'s player utility function. Another notation to be defined before carrying on; suppose that $\boldsymbol{a} \in \boldsymbol{A}$ is a strategy profile and $\boldsymbol{i} \in \boldsymbol{I}$ is a player; and then $\boldsymbol{ai} \in \boldsymbol{Ai}$ denote player $\boldsymbol{i}'s$ action in $\boldsymbol{a}$ and $\boldsymbol{a - i}$ denote the actions of the other $\boldsymbol{I - 1}$ players. The most important equilibrium concept in game theory is the concept of Nash Equilibrium [6]. A Nash equilibrium is an action profile at which no user may gain by unilaterally deviating. So Nash equilibrium is a stable operating point because no user has any incentive to change strategy. More formally, a Nash equilibrium is a strategy profile $\boldsymbol{a}$ such that for all $\boldsymbol{ai} \in \boldsymbol{Ai}$,

$$\boldsymbol{U}(\boldsymbol{ai}, \boldsymbol{a - i}) \geq \boldsymbol{U}(\tilde{a}\boldsymbol{i}, \boldsymbol{a - i}) \quad (2)$$

The ã, denote another action for the player $\boldsymbol{i}'s$. Pareto efficiency is another important concept for our application of game theory. An action profile $\boldsymbol{a} \in \boldsymbol{A}$ is said to be Pareto if there is no action profile $\tilde{a} \in \boldsymbol{A}$ such that for all $\boldsymbol{i}$**,**

$$\boldsymbol{U}(\boldsymbol{ai}) \geq \boldsymbol{U}(\tilde{a}\boldsymbol{i}) \quad (3)$$

In another word, an action profile is said to be Pareto efficient if and only if it is impossible to improve the utility of any player without harming another player.

		Player 2		
		L	**M**	**R**
Player 1	**U**	**3,2**	**3,0**	**1,1**
	D	**1,0**	**1,0**	**2,1**

Figure 5: An example of a Matrix game.

Simple two-player games are often represented in the form of a matrix. For an example game matrix which this paper will use to illustrate several of definitions, see as shown in figure 3. In this case, the players choose their moves simultaneously. Player 1 chooses a row, and player 2 chooses a column. The ordered pair in each box represents the payoff which each player receives when that "strategy profile" (choice of row and column) is realized; player 1's payoff is listed first in the ordered pair. In the game of figure 3, there are two pure-strategies of Nash equilibrium. The first is (U, L) and the second is (D, R). In addition, note that (U, L) is the only Pareto efficient point in the matrix. Hence, not every strategy of Nash equilibrium is Pareto efficient. In fact, in some games, none of the Nash equilibrium strategies are Pareto efficient. (For instance, the reader can be interested to see the vast literature on the Prisoner's dilemma [6])

Generally, repeated games with observable actions are a class of games which has been studied extensively. The basic idea in a repeated game with observable actions is that a simple game, the stage game, is played repeatedly by the same set of players. After each play of the stage game, all of the players learn what strategies were chosen by their opponents in the last round. As a result, players can condition their choice of strategies on past actions of their opponents. This gives rise to an enlarged strategy space; a strategy, $\boldsymbol{Si}$ for player $\boldsymbol{i}$ is now a map from the set of possible histories, $\boldsymbol{H}$, to the set of actions for player $\boldsymbol{i}$, $\boldsymbol{Ai}$ For example, consider the repeated version of the game in figure 3. In this case, the following set of strategies form a Nash equilibrium: Player 1 always plays U. Player 2 plays L unless player 1 has played D in a previous period, in which case player 2 plays M. The reason that this is a Nash equilibrium is simple. If player 1 always plays U, then player 2 plays L except after player 1 has played D, which is an optimal response for player 2. Similarly, for example, if player 2 will always play L unless player 1 has played D in the past, then always playing U is an optimal choice of strategy for player 1. Nonetheless, someone might thing that something seems wrong here. What if player 1 "accidentally" plays D in one stage? (Possibly player 1's action have got to be communicated through a noisy channel, for instance.) Then player 2 will play M forever after even though player 2 would be better off playing L or R. Player 2's strategy seems foolish off the equilibrium path. Thus, it is clear that there is a clear need for stronger equilibrium concept for repeated games. After each possible history $\boldsymbol{h} \in \boldsymbol{H}$, the players in essence start a new game, called the sub-game starting at $\boldsymbol{h}$. Like any other game, the concept of Nash equilibrium applies to the sub-game starting at $\boldsymbol{h}$. A sub-game perfect equilibrium is a strategy profile such that for every $\boldsymbol{h} \in \boldsymbol{H}$ the players will play a Nash equilibrium in the sub-game starting at $\boldsymbol{h}$ .The game in figure 4 has infinitely many sub-game perfect equilibrium [6]. One example of a sub-game perfect equilibrium is the strategy profile in which player 1 always plays U and player 2 always plays L. The concept of sub-game perfection can be extended to a much wider class of games than repeated games with observed actions. For a more thorough treatment of these and other topics in game theory, a simple introductory textbook to game theory and it generally works with information systems is [2]. An excellent intermediate book for game theory in engineering and wireless communication is [6].

4. Network Selection Mechanism in MIPv6 using Game Theory

This section presents the network selection mechanism, based on Game Theory. The mechanism is mostly founded by the help of the methodology presented in [8]. The mechanism consists of two steps; on the first hand, the first step focus on finding factors indicative of each network's weak points. Qualitative relations between the QoS parameters must be defined in this step in order to calculate the weight of each parameter and how it affects the overall QoS obtained. When this step is finished, priorities should be assigned to each parameter according to their weight. The higher a weight is, the higher the priority that should be given to the corresponding parameter. On the other hand, the second step investigates all the available networks in order to find the optimal choice. A questionnaire filled by the users of the networks might give a great understanding of the weight of each QoS parameter mentioned earlier. To estimate how each parameter fails to satisfy the system specifications, the ratio $\frac{\Delta x}{x} = \frac{|x - x\mu|}{x}$ is used to determine how much worse the network's performance is compared to the desired one. Where $(\boldsymbol{x})$ is a set of values, which considered as optimal, and ($\boldsymbol{x\mu}$) is the measurement mean value of each QoS parameter, ($\boldsymbol{x\mu}$) is always assumed to be worse than ($\boldsymbol{x}$) (i.e. $\boldsymbol{x\mu} < x$ or $\boldsymbol{x\mu} > x$ for the values considered to be larger or smaller the better respectively). Through the use of this ratio, the mechanism manages to assign each parameter a weight proportional to the extent at which it fails to satisfy the specifications. Moving forward to find the optimal solution, matrices are used to synthesize all problem-deciding factors. Using the matrix form the elements are compared in each level of the hierarchy in order to provide a degree of preferences of one parameter against the other. After a repetitive process provides the relative weights, with which the decision elements participate in the configuration of the final objective.

To sum up; the mechanism classifies the parameters into three series of elements; larger-the-better, smaller-the-better, and nominal-the-best. Then it defines the lower, moderate or upper bounds of the series. After normalizing the individual entities and defining the ideal series, the mechanism calculates the level of similarity and variability between the elements and describes the relationship between them. More theoretical examples and details on the proposed network selection mechanism can be found in [9]. This mechanism leads to propose the Game based Multi-interface Fast-handover Mobile IPv6 (GMFMIPv6), which is an extension to the MFMIPv6 introduced in [5]. The reason behind adding the Game Theory to the MFMIPv6 [5] is; to make sure that the MN has the ability to choose the right access point at the right time depending on the information received from those access points.

To this end, in order to evaluate the performance of the proposed mechanism, we implement a similar design of the MFMIPv6 simulator by using ns-2 [10] and its extension MobieWan [11] introduced in [5]. One more wireless interface was added and one channel, the game controller was added between the network interfaces (NetIF0 and NetIF1 shown in figure 4 below), which will decide which AR to go with.

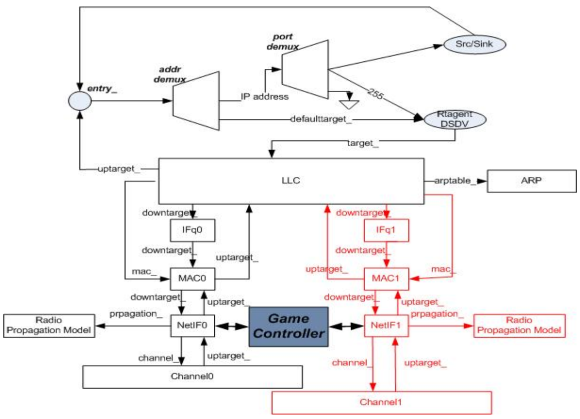

Figure 6: Two Interface MN.

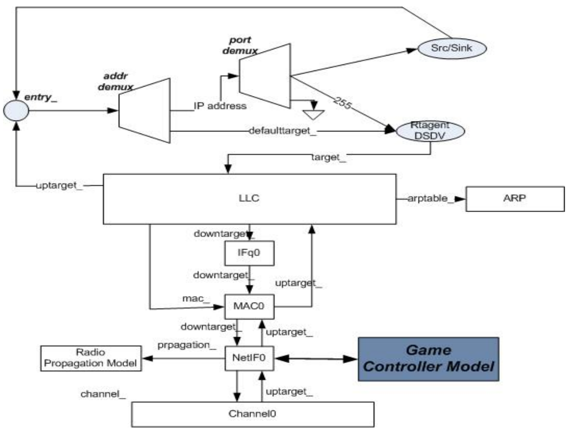

Figure 7: Single Interface MN.

The network interface receives all the packets at the node channel from other nodes or access points, each transmitted packets is stamped by the interface with the meta-data related to the transmitting interface [10]. The meta-data in the packet header includes information such as, transmitting power, wavelength, available QoS, security authentication etc., for the transmitted packets. The Game Controller is to be inserted between the network interfaces in the MN, the game controller is going to extract the packet header in the same way used in the propagation model, where the meta-data in the packet header is used by the propagation model to determine if the packet has the minimum power to be received and/or captured and/or detected. When the MN sends and receives the RtSolPr message and PrRtAdv message, the format of these messages described in details in [1], the game controller will know the source of each PrRtAdv message and extract the QoS information from it, and the MN will decide which AR is the best to go with by using the mechanism explained in section “3”. The MN will send the address of the NAR to the PAR by the MFBU message, explained in section “2”. Similar to the MFMIPv6 [5], the game decision will be based on the information received on the PrRtAdv message. Then, using the MFBU message, the winner (i.e. the access point that offers the best services) ID will be sent to the PAR in order to forward the packet to it, as shown in figure 4 above. During the game, the MN might face different cases; on the first hand, If there were two or more AR’s, which can offer the same services to the MN (i.e., the Nash equilibrium case), the MN will not face any problem in choosing any one of them at that point, as far as, all of them are offering the same QoS required by the applications. On the other hand, if one of the AR’s managed to improve the offered QoS to the MN, the MN will switch to it (i.e., the Pareto efficient case), where it is impossible to improve the utility of one player without harming the others.

5. Simulation Scenario and Results

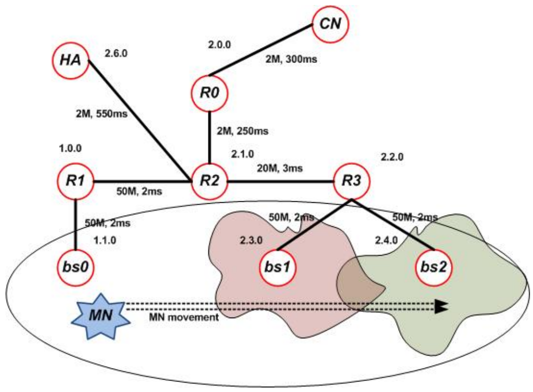

Figure 8: Single Interface MN Scenario.

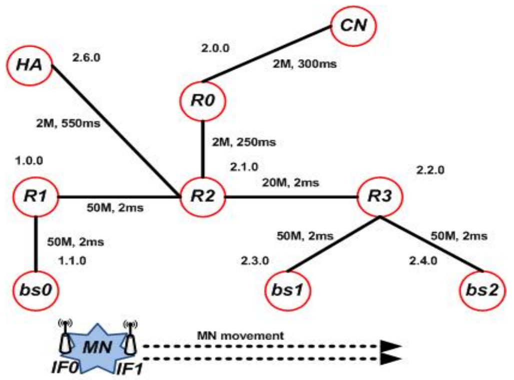

Figure 9: Two Interface MN Scenario.

The network topology of the simulation is shown in figure 6, at the beginning of the simulation the MN is connected to ‘bs0’. We increased the coverage of the first base station ‘bs0’ in order to make the simulation looks similar to the one shown earlier in figure 1. The MN should choose the right access point while moving towards the third one ‘bs2’ according to the bandwidth and delay of the received TCP traffic form the Correspondent Node (CN).

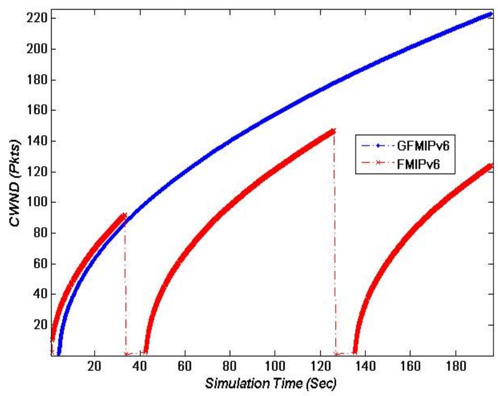

Figure 10: single interface, congestion window size over the simulation time.

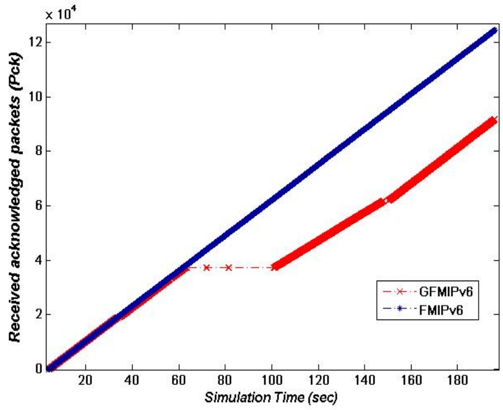

Figure 11: single interface, number of received ACK over the simulation time.

For the case of the single interface MN, the results show two handover instants; the first one at 36.8 second, and the second one at 129.3 second. The congestion window variations for the two protocols, FMIPv6 and GFMIPv6 (Game Theory based Fast-handover Mobile IPv6) are shown in Fig. 10. The congestion window for the case of the FMIPv6 shows sharp drops while the MN handed over from one AR to another. That's because of the severe reordering by tunneling to the NAR that causes TCP congestion control. On the other hand, the congestion window in the GFMIPv6 as the MN didn't face any handovers during the simulation time. The Game Theory force the MN to stay with the same AR as it offers a better service in terms of bandwidth and the overall end-to-end delay of the received packets. The MN moves with a speed of a 10 meter per second; with the case of the FMIPv6, the overall throughput shows massive drops during the handovers. However, the other case of the GFMIPv6 shows a much better improvement as the MN never faced any handovers. In Fig. 11, the overall number of successfully received packets in the network is shown. The GFMIPv6 protocol shows how the number of received packets kept on increasing without any disturbance, which shows the higher performance of the network selection mechanism defined in this paper.

One the other hand, in the case where the MN has two wireless interfaces, the result shows the number of received packets during the simulation time and the overall end-to-end delay variations between the MIPv6 [1], MFMIPv6 [5], and the GMFMIPv6 proposed in this paper. This scenario studies three handovers during the simulation time; at, 20.12 sec, 40.32 sec, and 96.89 sec between, 'bs0' to 'bs1', 'bs1' to 'bs2', and 'bs2' to 'bs0', respectively. However, in the case of the GMFMIPv6, the MN does not have to do the second handover. In fact the handovers that it will face are at 20.12 sec, and 96.89 sec from 'bs0' to 'bs1' and from 'bs1' to 'bs0', as there is no need to handover to the other access point when they both offer the same bandwidth and delay, the MN movement is shown in figure 1. We can see from the results shown in figure 12, that the throughput of the GMFMIPv6 is higher than that of the MFMIPv6 and MIPv6, because of the higher number of received packet at the CN from the MN during the simulation time. Moreover, the number of received packets, as the simulation time goes on, shows the higher performance of the network selection mechanism in the GMFMIPv6. It can easy be shown that the MN with the GMFMIPv6 didn't face the last handover, as the number of acknowledges packets didn't changed. The overall end-to-end delay is shown in the figure 13 above, again the game theory managed to force the mobile node not to make the handover around the 40th second of the simulation time, by which keeping the end-to-end delay steady and better than the other two cases.

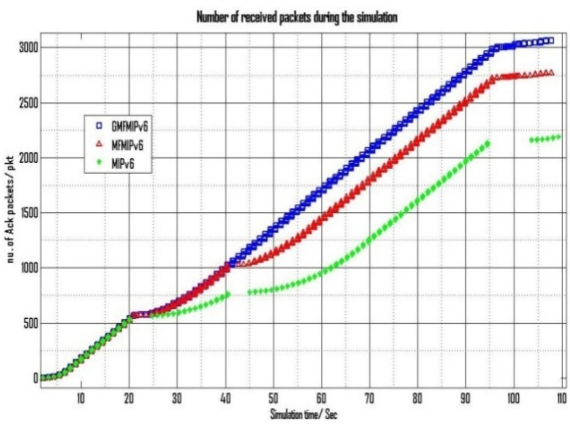

Figure 12: two interfaces, number of received ACK over the simulation time.

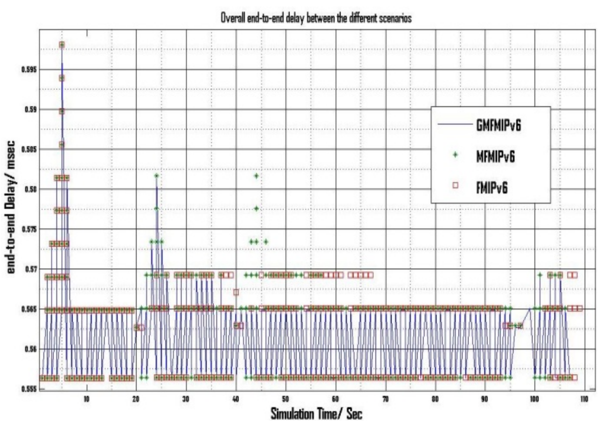

Figure 13: two interfaces, overall end-to-end delay over the simulation time.

6. Conclusion

This paper presents a novel methodology for combining Game Theory and wireless network selection mechanisms in single interface mobile devices. Moreover, it presents an extension to the FMIPv6 and the MFMIPv6, by which the MN can decide whether to make the handover or not when it have multiple CoA's and/or multiple wireless interfaces. The proposed mechanism can indicate the best access point to choose during the handover procedure by sending the "winner" destination address (i.e. the NAR address) to the PAR using the FBU message. Simulation results show that the proposed mechanism increases the number of received packets during the simulation time and increases the overall throughput of the network, which improves TCP performance in mobile networks, by avoiding crashing the congestion window during handovers. To this end, the proposed mechanism (i.e. GFMIPv6 and GMFMIPv6) can be used as one of the promising handover protocols for single interface mobile nodes with multiple CoA's and for multiple interfaces mobile nodes in the next generation mobile Internet.

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