A Trusted Handoff Decision Scheme for the Next Generation Wireless Networks

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Summary
Fourth Generation Wireless Networks (FGWN) consists of heterogeneous networks managed by different operators (or service providers). The provision of continuous services for mobile nodes is a main issue for the FGWN, Thus, it is necessary to provide seamless handover while moving in such environment. Moreover, the establishment of trust relationships between FGWN's entities poses a major challenge. In this regard, exchanging trust information between networks and mobile nodes is an important factor which guarantees a trusted handoff decision. In this paper, we will present a Trusted Distributed Vertical Handoff Decision (T-DVHD) scheme, which provides trusted and seamless vertical handover. The simulation outputs show good performance of the T-DVHD in term of handoff delay, blocking rate and throughput.

Key words:
Handover, Handoff Decision, Wireless Network, Mobile Node, Quality of Service (QoS).

1. Introduction

Fourth Generation Wireless Networks (FGWN) consists of heterogeneous networks managed by different operators, with objective to exploit the "high data-rates" of wireless local area networks. A typical scenario of such wireless integration is the following: third-generation (3G), Universal Mobile Telecommunications System (UMTS) (large-coverage, higher-cost, and low-bandwidth) and 802.11x WLAN (high-bandwidth, low-cost and short-coverage). These wireless access networks are combined to provide a ubiquitous environment of wireless access for mobile terminals equipped with multiple network interfaces.

One of the main issues for the FGWN is the mobility, with which users can benefit of continuous services while moving between networks. While moving mobile user may switch from a network to another, which occurs when the QoS offered by the network, to which the mobile user is connected, decreases under certain predefined quality level, the switch mechanism is known as *handover*.

Handover is the mechanism with which a mobile user redirects its connection from an old network to a new one, the handoff delay must be as small as possible in order to make seamless handover. Moreover, there are two types of handover; Horizontal and Vertical handover (Fig.1). Horizontal Handover (HHO) occurs when the mobile user is switching between networks supporting the same technology (e.g. UMTS->UMTS, WiMax->WiMax), while Vertical Handover (VHO) is used when the mobile user redirects its connection from a network to another and these networks support different types of technology (e.g. UMTS->WiMax, WiMax->WiFi).

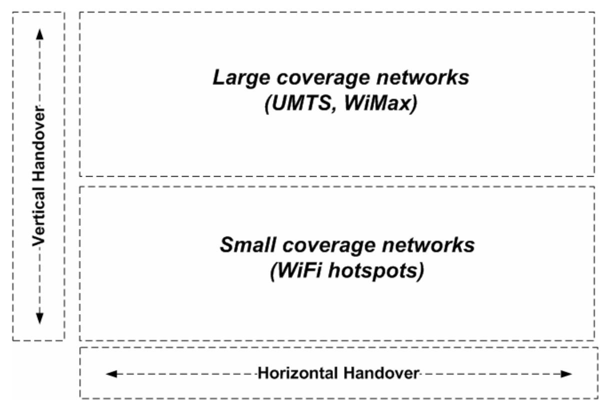

Fig 1. VHO vs HHO

The handover mechanism consists of four phases: Handover Initiation, System Discovery, Handover Decision and Handoff Execution.

- The *Handover Initiation phase* triggers the handover process basing on modifications of some criteria value, such as signal strength, link quality.
- The *System Discovery phase* is considered as the information gathered phase or preparation phase. In which mobile user discovers its neighbor networks and exchanges information about the QoS offered by these networks.

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- The *Handover Decision phase* consists of comparing the offered QoS by neighbor networks and the QoS required by the mobile user, and basing on this comparison the decision maker makes the decision to which network the mobile user has to redirect its connection.
- The *Handoff Execution phase* is responsible for the establishment and release of the connections, as well as the invocation of the security services.

Handover decision phase is in the scope of our work, as it's mentioned above the handover decision is used by the decision maker to choose from a set of available networks the suitable network to which the mobile user has to redirect its connection. We can classify the handover decision into two types: Vertical Handover Decision (VHD) and Horizontal Handover Decision (HHD).

- The HHD is the process achieved when a mobile user is making a HHO. This process is based only on the signal strength of the network's Point of Attachment (PoA) to make the decision. As the mobile user is moving between networks that support the same technology.
- The VHD process occurs when the mobile user is achieving a VHO. The provision of seamless vertical handoff requires the design of a robust VHD scheme. Moreover, as the mobile users are moving in an environment with different networks supporting different technologies, the VHD depends on different criteria such as bandwidth, cost, power consumption, network condition, user preference and security. Thus, the VHD is made basing on the Home Network's (HN)[1] conditions and the quality offered by the Visiting Network (VN)[2].

2. Related Works

Several proposals and approaches considering the vertical handoff decision algorithms were proposed in the literature. In [1] the vertical handoff decision is formulated as a fuzzy multiple attribute decision making problem. The proposed handoff scheme consists of two parts: the first one is to process multiple criteria by using a fuzzy logic inference system, while the second one is to apply a Fuzzy MADM access network selection function to select a suitable network. In [3], a performance comparison among SAW, TOPSIS, Grey Relational Analysis (GRA), and the Multiplicative Exponent Weighting (MEW) for vertical handoff decision is presented. In [4], the authors formulate the handoff decision mechanism as an optimization problem. Each candidate network is associated with a cost function which depends on a number of criteria, including the bandwidth, delay, and power requirement. In [6], the authors propose a generic handoff decision function. A set of criteria is used in order to evaluate the quality of the available networks. A smart handoff decision mechanism is proposed in [9], authors propose two phases to accomplish the handoff decision: priority phase and normal phase, in priority phase a list of available networks is created, while in the normal phase a score function is used, in order to choose the best available network from the list, the function consists of three criteria: link capacity, cost and power consumption. In [14], the vertical handoff decision is evaluated via a handoff cost function and a handoff threshold function which can be adapted to changes in the network environment dynamically.

All of these approaches mainly focused on the vertical handoff decision, assuming that the handoff decision processing task is performed on the mobile node side. Such processing task requires a non negligible amount of resource to exchange information messages between mobile node and neighbor networks in order to accomplish the discovery phase of the handoff process. This processing task impacts the mobile node performance in term of processing delay, which in turn impacts the handoff delay and the power consumption. Through our work we call such schemes: Centralized Vertical Handoff Decision (CVHD).

In the following section we will present our Trusted Distributed Vertical Handoff Decision (T-DVHD).

3. The Trusted Distributed Vertical Handover Decision (T-DVHD)

In our work we propose a Trusted Distributed Vertical Handover Decision (T-DVHD) scheme for the FGWN. T-DVHD distributes the decision task among networks in order to decrease the processing delay caused by exchanging information messages between mobile node and neighbor networks. To do so, we delegate the calculation task and implement the user profile among neighbor networks. In order to distribute the processing task, the vertical handoff decision is formulated as a Multiple Attribute Decision Making (MADM) problem. Several MADM methods are offered such as: Simple Additive Weighting (SAW), Technique for the Order Preference by Similarity to Ideal Solution (TOPSIS), Grey Relational Analysis (GRA) and Multiplicative Exponent Weighting (MEW). In our work we use SAW method in a distributed manner.

Neighbor networks are managed by different operators or service providers, delegating the calculation task among

[1] HN: is the network in which the mobile user initiates its connection
[2] VN: the network to which the mobile user decides to redirect its connection.

these networks risks that the information received by the mobile node to make the decision may be falsified (e.g. the information representing the network quality doesn't reflect the real network's condition). Receiving falsified information may cause multiple handoff events, which may increase the processing delay. Thus, the establishment of trust relationships in such environment poses a major challenge. In this regard, exchanging trust information between networks and mobile node is an important factor which guarantees a trusted handoff decision and avoids the unnecessary handoff events. For that, we propose an extension of the DVHD scheme, the Trusted Distributed Vertical Handoff Decision (T-DVHD) scheme.

3.1 Scenario

Before describing our scenario (system model), we consider important to state the underlying assumptions. Hence, we consider that the mobile node is moving in an overlapping area covered by groups of wireless networks providing small and large coverage area, and managed by different Service Providers (SPs). The mobile node runs a Voice over IP (VoIP) application that requires an appropriate QoS level.

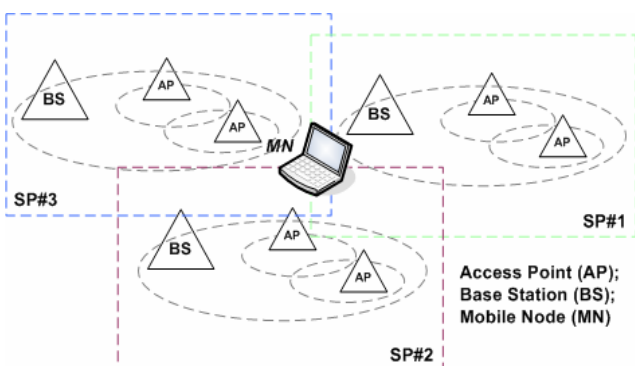

Fig 2. Scenario Model

Networks are divided into three categories: the Home Network (HN) which is the network in which the mobile node has initiates its connection, the Target Visiting Networks (TVNs) which are the networks to which mobile nodes intend to roam into, and the Visited Network (VN), which is the best network chosen by the mobile node using the T-DVHD scheme. These networks cover the entire mobility area, as illustrated in Fig.2.

3.2 Distributed Vertical Handover Decision (DVHD)

Centralizing the VHD process at the Mobile Node (MN) has a major effect, increase the processing delay, caused by exchanging information messages between the MN and the neighbor networks. Increasing the processing delay will increase the overall handover delay and the mobile node's power consumption.

In order to avoid the effect caused by the CVHD, we propose a Distributed Vertical Handover Decision (DVHD) scheme. The DVHD goal is to decrease the processing delay by decreasing the exchanged messages between the MN and the neighbor networks. Thus, DVHD delegates the handoff calculation to the Target Visited Network (TVN)[1] rather than the mobile node, as some approaches propose and implement a table representing the user profile (Tab.1) among these TVNs. Furthermore, the DVHD also takes into account: latency and cost (in money) as evaluation metrics to select heuristically a suitable Visited Network (VN). These metrics are gathered as a Multiple Attribute Decision Making (MADM) access selection function.

Tab.1. User Profile

Classes	*Latency*	*WL*	*Cost*	*WC*
1	*L1*	*WL1*	*C1*	*WC1*
2	*L2*	*WL2*	*C2*	*WC2*
3	*L3*	*WL3*	*C3*	*WC3*

3.2.1 Distributed Network Selection Algorithm

3.2.1.1 Network Selection Function (NSF)

We formulate the network selection decision process as a MADM problem, which evaluate a set of networks using the multiple criteria Network Selection Function (NSF). NSF is an amalgamation of a set of parameters such as network condition, bandwidth, power consumption, cost, latency and security. This function measures the Network Quality Value (NQV) of each TVN. So, the mobile node can select as Visited Network (VN), the TVN with the highest NQV value.

The generic weighted NSF is defined as depicted by (1):

$$\mathrm{NQV}_i = \sum_{i=1,\, j=1}^{N,\, n_P^+} W_j * P_{ij} \qquad (1)$$

Where, NQV_i represents the quality of the ith TVN. P_{ij} represents the jth parameter of the ith TVN. W_j is the weight of the P_{ij}, it indicates the importance of each parameter. N is the number of TVNs, while n_P^+ is the number of parameters.

[1]TVN: Network to which the mobile node may connect.

The HN, based on the user profile, assigns different "weights" to the handoff decision parameters in order to determine the level of importance (i.e. user preference) of each parameter. As illustrated in (2), the sum of these weights must be equal to one,

$$\sum_{j=1}^{n_P^+} W_j = 1 \qquad (2)$$

As stated before, in our work we use only two parameters: Latency and Cost (in money), so, the evaluation NSF is as follow:

$$NQV_i = (W_L * L_i) + (W_C * C_i) \qquad (3)$$

Where, L_i is the latency (depends on the network type) of the i^{th} TVN, and C_i is the cost of the service of the i^{th} TVN. L_i and C_i have a normalized value.

3.2.1.2 Distributed Decision Scheme

The DVHD scheme is based on the Simple Additive Weighting (SAW) method; however we apply it in a distributed manner. Thus, we place the computing processing among TVNs rather than on the mobile node. DVHD allows the mobile node to choose the "best" TVN toward which it will connect.

SAW method applies the NSF on the quality parameters of each TVN, by using the matrix Mat.1 containing the quality parameters of each TVN. In our case and in order to distribute the computing task, the matrix consists of (L_{off},C_{off}) and (L_{req}, C_{req}) the offered and required (i.e. user requirements are retrieved from the user profile table – Tab.1) parameters respectively. Thus, each TVN computes its NQV and sends it to the mobile node.

$$M = \begin{bmatrix} B_{off} & C_{off} \\ B_{req} & C_{req} \end{bmatrix} \qquad \text{(Mat 1)}$$

The weights for the latency and the cost (W_L W_C) are gathered in the vector Vect.1

$$W = \begin{bmatrix} W_L & W_C \end{bmatrix} \qquad \text{(Vect 1)}$$

After scaling[1] the matrix's elements, the matrix Mat.1 is weighted and the NQV is calculated.

Therefore, the DVHD scheme consists on the following steps:

- The mobile node initiates the handoff process, caused by the degradation of the offered quality or the availability of TVNs offering better quality then the quality offered by the network to which the mobile node is connected. Then it sends a handoff request message to all available TVNs, this message includes the mobile node identity and the user profile reference.
- Each TVN computes its NQV, by retrieving the appropriate User-Profile from the User-Profile table (Tab.1), then it creates the decision matrix ((Mat.1) and the weight vector (Vect.1), and applies the MADM method (SAW) using (1) on the required (L_{req}, C_{req}) and offered (L_{off}, C_{off}) parameters as in (4). Then it sends its NQV to the mobile node.

$$NQV = \begin{bmatrix} L_{off} C_{off} \\ L_{req} C_{req} \end{bmatrix} * \begin{bmatrix} W_L \\ W_C \end{bmatrix} \qquad (4)$$

- Finally, the mobile node puts all received NQVs in a list, then it picks up the highest NQV and considers that the corresponding TVN is the VN, to which it redirects all connections.

3.3 Trusted Distributed Vertical Handover Decision (T-DVHD)

Distributing the VHD process provides benefits in term of processing delay, but, as the computing task is performed at the TVNs side a trust problem occurs. TVNs may falsified their NQV (e.g. economic reason, TVN may send quality value that doesn't reflect its real condition), which impacts the handoff delay. Receiving falsified NQV from a TVN, as the decision is based on NQVs, may effect the mobile node decision. So, if the mobile node chooses a TVN that doesn't meet its requirements, it may be obliged to initiate another handoff process. Thus, multiple handoff events may occur, which increase the vertical handoff delay.

In order to avoid multiple handoff events we propose an extension of the DVHD scheme, the Trusted Distributed Vertical Handoff Decision (T-DVHD), which guarantees a trusted handoff decision, by offering a knowledge level about the mobile node's mobility environment.T-DVHD

[1] SAW needs a comparable scale for all elements in the matrix.

affects a *Level of Trust (LoT)* parameter for each available TVN, the value of this parameter is updated using a *Trust-test function*. Thus, when the mobile node chooses the VN, and before achieving the handoff execution phase, it compares the LoT value of the chosen network with a predefined threshold (the threshold value depends of the running application). If the test is positive then the mobile node redirects its connection to the chosen VN and initiates a *Trust-test function* used to accommodate the mobile node knowledge. If the test is negative the mobile node picks up another available TVN and executes the Trust-test function for this network.

3.3.2 T-DVHD scheme

As illustrated in Fig.5. Firstly, the mobile node sends its User-Profile reference to each TVN, which in turn retrieves the mobile node requirements from the User-Profile table (Tab.1) and applies the SAW decision method to compute the NQV. Each TVN sends its NQV to the mobile node, which groups them in a list. Then, it picks up the highest NQV from the list and before connecting to the appropriate TVN it initiates the Trust process.

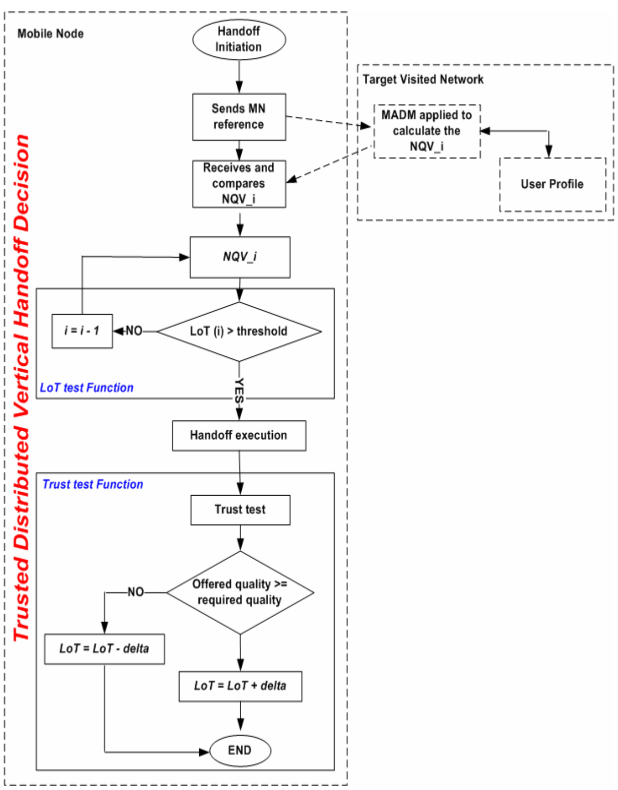

Fig 3. The T-DVHD Scheme

The Trust process consists of two functions: the LoT-test function and Trust-test function.

3.3.2.1 LoT-test function

The *LoT-test function* is initiated after that the mobile node receives all NQVs from the different TVNs and build its NQVs list. Its goal is to test if the chosen TVN is or not a trusted network. A LoT table (Tab.2) is placed at the mobile node side, this table contains the TVNs identities associated to LoT values, which are updated by the Trust-test function (Fig.4).

Tab.2. LoT Table

Network Reference	***LoT***
Network_1	L1
Network_2	L2
…	…
Network_n	Ln

Therefore, before that the mobile node switches to the chosen TVN the LoT-test function is initiated and the algorithm in Fig.3 is applied on the LoT of the appropriate TVN (corresponding to the highest NQV). The LoT value corresponding to the chosen TVN is retrieved from the LoT-table and is compared to a predefined threshold (the threshold value depends on the running application. e.g. If the application is delay sensitive, the threshold value must be high, in order to avoid multiple handoff events). If the LoT-value is greater or equal to the threshold, then the mobile node switches to the VN and initiates the Trust-test function. If not, if another TVN is available, its LoT value is retrieved from the LoT-table and the LoT-test is applied on this value. Finally, if no more NQV in the list or the maximum handoff delay is exceeded, the handoff is blocked.

If $LoT_i >= threshold$
    Connect to the TVN_i
    Initiate Trust-test function
else if $LoT_i < threshold$ *{*
  if *(suitable-TVN available)*
      $i = i + 1$
      Goto 01 (test another network)
  else if *(no suitable-TVN)* ***OR*** $H_D > Max\_H_D$
     Handoff blocked

Fig 4. LoT-test Function

3.3.2.2 Trust-test function

The Trust-test function is initiated once the mobile node connects to the VN. The mobile node executes this function in order to accommodate knowledge about the neighbor TVNs. This is done by updating the LoT table using the algorithm illustrated in Fig.4.

If $Q_{off} < Q_{req}$
    $LoT_i = LoT_i - delta^-$;
else
    $LoT_i = LoT_i + delta^+$;

Fig 5. Trust-test Function

As presented in Fig.4, the test compares the quality[1] offered (Qoff) by the VN with the quality required (Qreq) by the mobile node. In case Qoff < Qreq (e.g. if a remarkable quality degradation appears after connecting to the VN), the LoT value is decreased by $delta^-$ ($delta^-$ value is fixed depending on the type of the running application by the mobile node, e.g. VoIP application is delay sensitive, thus $delta^-$ has to have a high value in order to avoid multiple handoff events). Else if Qoff >= Qreq the LoT value of the considered VN is increased by $delta^+$.

3.4 Simulation

In this section, we provide the evaluation parameters used to analyze the performance of the proposed T-DVHD scheme as well as the output and analysis of the simulation. In our work we consider that mobile nodes are moving uniformly in an area covered by N networks managed by three Service Providers (SP_i, i = 1...3). Mobility area consists of different PoA supporting two types of technologies; WiMax and WiFi. These PoAs offer different characteristics in term of coverage and QoS (latency). WiMax Base Station (BS) covers the entire mobile node's mobility area and is managed by the SP_1, while WiFi Access Points (APs) are uniformly distributed in the BS's coverage area (e.g. hotspots) and are managed by the SP_2 and SP_3.

Latency provided by the networks is in the range of [150…400] milliseconds (ms), and the Cost (in money) is in the range of [0…5]. We assume that the user is running a VoIP application, which needs a stable amount of latency (roundtrip voice delays <= 300 ms [7]). Finally, we assume that mobile node is always covered by at least two networks.

3.4.1 Evaluation Parameters

Different evaluation parameters are used, in order to evaluate the T-DVHD scheme; Decision-Processing Delay, Handoff Blocking rate, Handoff Events and Throughput.

[1] Quality is the QoS offered by the network or required by the mobile node, such as: latency, loss packet, jitter, etc.

Decision processing delay is the processing time needed by the mobile terminal to make the decision toward which network to handoff.

Handoff Blocking occurs when the mobile terminal chooses an unsuitable VN. *Handoff blocking rate* represents the percentage of calls that did not finish their services. The handoff may be also blocked when the mobile node exceeds the maximum allowed handoff delay. As handoff events cause additional delay, successive handoff events increase the risk that the handoff is blocked.

Multiple handoff events occur **w**hen the mobile node chooses malicious TVN that provides falsified quality value (i.e. NQV). In this case, another handoff event may be performed as the switched VN doesn't provide the appropriate quality, which adds additional delay to the handoff process. *Handoff Events* parameter reflects the number of handoff achieved by the mobile node.

Throughput refers to the data that are sent by the mobile node after a set of matching decisions during a defined period. It reflects the robustness of the decision scheme.

3.4.2 DVHD Output and Analysis

We evaluated our proposed DVHD scheme by comparing it with the Centralized Vertical Handoff Decision (CVHD) scheme. Two scenarios were simulated: the first scenario considers that the mobile node is overlapped by two TVNs. While in the second scenario, the mobile node is overlapped by four TVNs. The simulation output of each scenario presents the average of 100 runs of terminating simulations. In each of them we calculate the mean of decision time and throughput for 1000 handoff decisions.

Fig.6 and Fig.7 show that by distributing the calculation task among TVNs instead of the mobile node the processing delay at the mobile node side decrease significantly. The results show that the larger is the number of available TVNs, the higher is the processing delay when making the handoff decision. Results show that by using the DVHD scheme we can reduce the decision processing delay. Moreover, we can also infer that the number of available TVNs has an impact on the decision processing delay.

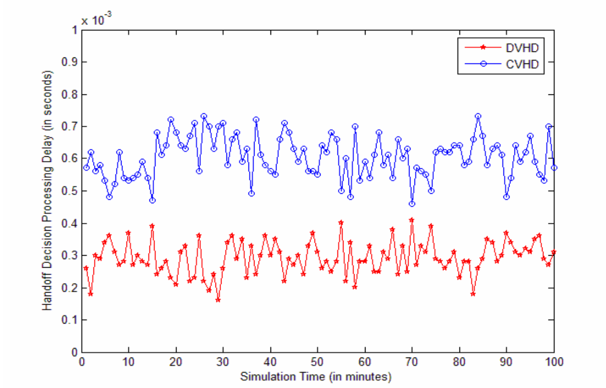

Fig 6. Decision-Processing Delay (2 available VNs)

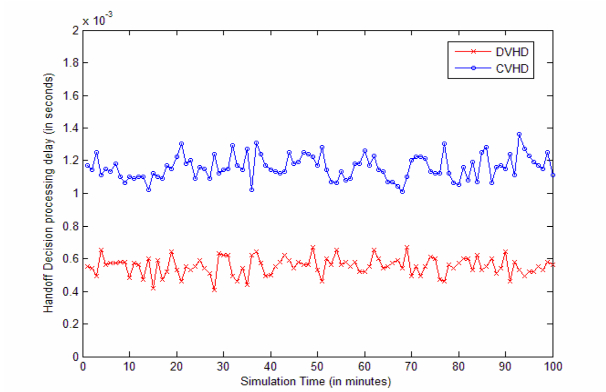

Fig 7. Decision-Processing Delay (4 available VNs)

Furthermore, Fig.8 shows the handoff blocking rate, as the results show the blocking rate decrease by using DVHD scheme, due to the reduction of the processing delay.

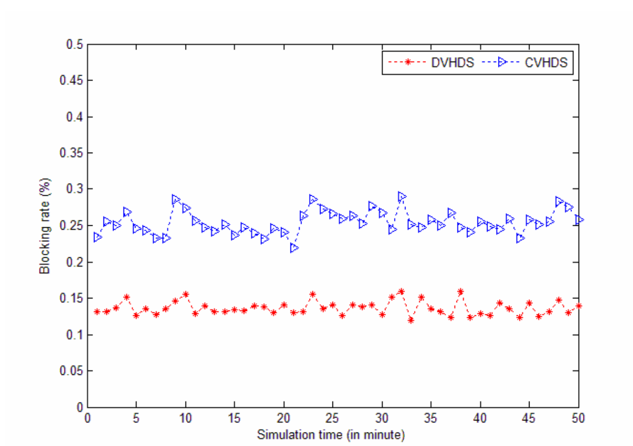

Fig 8. Handoff Blocking rate

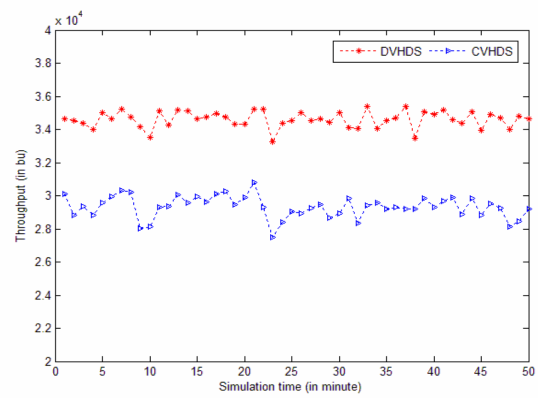

Fig 9. Throughput

Finally, Fig.9 shows that DVHD, due to the lower level of the handoff blocking rate, provides higher throughput level than the throughput provided by the CVHD.

3.4.3T-DVHD Output and Analysis

The T-DVHD is evaluated by comparing it with the DVHD scheme. The simulation output of the used scenario presents the results of 50 runs of terminating simulations; each of them is the average of 200 handoff decision processes executed by the mobile node while moving uniformly between the different TVNs. For each of the handoff decision event, we compute the handoff delay, the handoff blocking rate and the throughput.

Fig.10 shows the number of unnecessary handoff events caused by untrusted decisions made by the mobile node using the DVHD scheme. We can clearly see that the handoff events (positive values in Fig.10) can attempt more than two events per decision, this multiple handoff events is caused by the falsified information provided by malicious TVNs. We can see also that, by using the T-DVHD scheme the mobile node avoids the unnecessary handoff events (negative values in Fig.10), as the mobile node doesn't choose the TVN as VN if it's a malicious network.

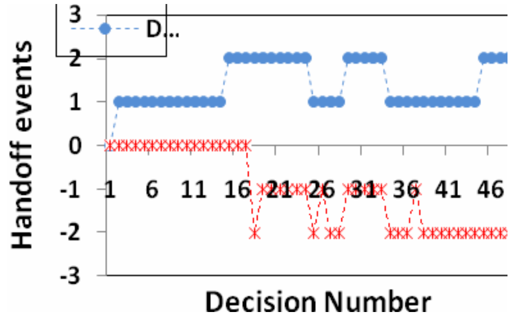

Fig 10. Handoff Events

Fig.11 demonstrates the relation between handoff blocking rate and handoff events. Thus, by using the T-DVHD scheme the mobile node avoids to redirect its connection to malicious TVN, even if the TVN provides the highest quality (i.e. NQV). Therefore, the handoff blocking rate is very low when we use the T-DVHD scheme compared to the DVHD without trust algorithm.

In Fig.12, it's clear that by using the T-DVHD, which decreases the unnecessary handoff events and in result the handoff blocking rate, the mobile node throughput is higher than the throughput when using the DVHD scheme. As the multiple handoff events cause packet loss and decrease the processing delay, it impacts the overall mobile node throughput. We can see in Fig.12 that the mobile node throughput using T-DVHD is an average of 350 Mb/s, while it is about 190 Mb/s while using the DVHD without the trust algorithm.

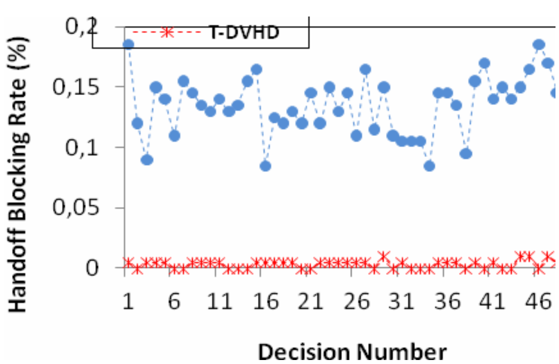

Fig 11. Handoff Blocking Rate

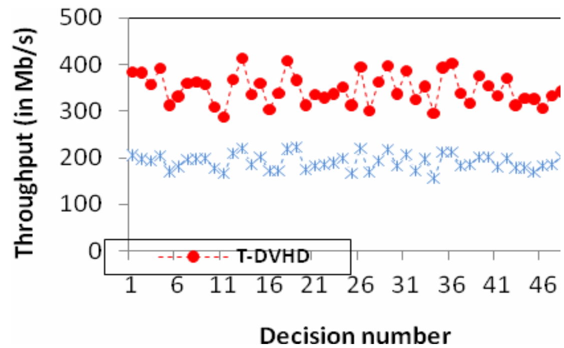

Fig 12. Throughput

Conclusion

In this work we present a Trusted Distributed Vertical Handover Decision (T-DVHD) scheme for the fourth generation wireless networks. The main goals of the T-DVHD are to decrease the processing delay and to make a trust handoff decision in a heterogeneous wireless environment. The simulation's results show the benefits of distributing the handoff decision, in term of processing delay, handoff blocking rate, handoff events and throughput.

References

[1] Yaw Nkansa-Gyekye and Johnson I. Agbinya, "Vertical Handoff Decision Algorithm for UMTS-WLAN", AusWireless 2007, IEEE Computer Society.

[2] Wenhui Zhang, "Handover Decision Fuzzy MADM in Heterogeneous Networks", WCNC 2004, IEEE Communications Society.

[3] Enrique Stevens-Navarro and Vincent W.S. Wong, "Comparison between Vertical Handoff Decision Algorithms for Heterogeneous Wireless Networks", IEEE - VTC 2006.

[4] W. Chen and Y. Shu, "Active Application Oriented Vertical Handoff in Next Generation Wireless Networks," in Proc. of IEEE WCNC'05, New Orleans, LA, March 2005.

[5] Jukka, Ylitalo, et al., "Dynamic Network Interface Selection in Multihomed Mobile Hosts", Proceedings of the 36th Hawaii International Conference on System Sciences, Hawaii, USA, Jan. 2003.

[6] Ahmed Hasswa, Nidal Nasser, and Hossam Hassanein, "Generic Vertical Handoff Function for Heterogeneous Wireless Networks", IEEE and IFIP International Conference - WOCN, Dubai, UAE, March 2005, pp. 239-243. .

[7] International Telecommunication Union. General Characteristics of International Telephone Connections and International Telephone Circuits. ITU-T, G.114, 05/2003.

[8] Michael Angermann, and Jens Kammann, "Cost for Decision Problems in Wireless AdHoc Networking", Proceedings of IEEE CAS 2002, Pasadena, CA (USA).
[9] Shu-Jen Chen Ching-Lai Hwang and Frank P.Hwang, "Fuzzy Multiple Attribute Decision Making", Springer-Verlag 1992, Berlin.
[10] Ling-Jyh Chen, Tony Sun, Benny Chen, Venkatesh Rajendran, Mario Gerla, "A Smart Decision Model for Vertical Handoff", ANWIRE 2004, Athens, Greece.
[11] Manoreet Sugh Dang, and al., "Fuzzy Logic Based Handoff in Wireless Networks", Proceedings of IEEE VTC 2000 Spring Tokyo, Japan.
[12] Hosik Cho, Eun Kyoung Paik, and Yanghee Choi, "Movement-aware Mobile Router Advertisement for Power Saving in Vehicular Mobile Networks", World Wireless Congress 2004, pp. 642-645, San Francisco, USA.
[13] Min Liu, Zhong-Cheng Li, Xiao-Bing Guo, Eryk Dutkiewecz and De-Kui Zhang, "Performance Evaluation of Vertical Handoff Decision Algorithms in Heterogeneous Wireless Networks", IEEE Globecom 2006 proceedings.
[14] H.J. Wang, R. H. Katz, and J. Giese, "Policy-Enabled Handoffs across Heterogeneous Wireless Networks", Proc. of ACM WMCSA, 1999.
[15] A. Hassawa, N. Nasser, and H. Hassanein, "Tramcar: A Context-Aware Cross-Layer Architecture for Next Generation Heterogeneous Wireless Networks", in Proc. of IEEE ICC'06, Istanbul, Turkey, June 2006.
[16] Nidal Nasser and Hossam Hassanein, "Adaptive Call Admission Control for Multimedia Wireless Networks with QoS provisionning", International Workshop on Mobile and Wireless Networking (MWN), Montreal, Canada, August 2004
[17] G.Corazza, D.Giancristofaro, and F.Santucci, "Characterization of Handover Initialization in Cellular Mobile Radio Networks", in proceedings of IEEE VTC'94, pp.1869-1872, June 1994.
[18] R. Tawil, O. Salazar and G. Pujolle, " Vertical Handoff Decision Scheme Using MADM for Wireless Networks", IEEE Wireless Communications and Networking Conference (WCNC’2008), IEEE Communications Society.

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