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# Experimental Evaluation of Mobility Anchor Point Selection Scheme in Hierarchical Mobile IPv6

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***Abstract*—**Hierarchical Mobile IPv6 (HMIPv6) was designed to support IP micro-mobility management in the Next Generation Networks (NGN) framework. The main design behind this protocol is the usage of Mobility Anchor Point (MAP) located at any level router of network to support hierarchical mobility management. However, the distance MAP selection in HMIPv6 causes MAP overloaded and increase frequent binding update as the network grows. Therefore, to address the issue in designing MAP selection scheme, we propose a dynamic load control mechanism integrates with a speed detection mechanism (DMS-DLC). From the experimental results we obtain that the proposed scheme gives better distribution in MAP load and increase handover speed.

***Keywords*—**Dynamic load control, HMIPv6, Mobility Anchor Point, MAP selection scheme

## I. Introduction

THE Next Generation Networks (NGN) is expected to provide seamless handover in very high speed wireless network environment. There's crucial needed of very sophisticated protocols to support NGN QoS requirements. The Internet Engineering Task Force (IETF) has developed IP version 6 (IPv6) to anticipate address space and internet growth. In IPv6 protocol, the Mobility Header is identified by a Next Header value in IPv6 Header. Therefore IPv6 need a mobility support to ensure packets destined to a mobile node (MN) is reachable while it is away from its home address [1].

Mobile IPv6 (MIPv6) allow transparent routing of IPv6 packets to MNs. Although it supports mobility, it has problems on supporting seamless handover due to high delay. Every time MN move to new access router, it acquires new Care-of Address (CoA) and must notify Binding Update (BU) to Home Agent(HA) and Correspondent Node (CN) for each handover. The delay cannot be avoided when the distance growing among MN and it's HA.

Hierarchical Mobile IPv6 (HMIPv6) [2] is based on MIPv6 which aims to reduce the signalling amount between the MN, its CNs and, its HA. By the usage of a new node called Mobility Anchor Point (MAP), it can improve the handover speed. Therefore the furthest MAP selection in HMIPv6 can be a MAP overload and increase frequent binding update problem as the network grows. It's only suitable for fast MNs that will perform frequent handoffs because the MNs reduce the changing of MAPs. Hence, without specific an efficient
MAP selection scheme can affect the system performance and supporting seamless handover.

We propose an enhanced MAP selection scheme that integrates the distance MAP selection scheme with dynamic load control mechanism (DMS-DLC). Besides, we also improve the distance-based enhanced with speed detection mechanism to achieve MAP load control management and support seemless handover in HMIPv6.

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## II. Hierarchical Mobile IPv6 (HMIPv6)

In MIPv6 all packets sent to an MN must be routed first to the MN's home subnet and then forwarded to the MN at its current location by its HA. The design of MIPv6 does not attempt to solve all general problems related to the use of MNs or wireless networks. Specifically this protocol does not solve local or hierarchical forms of mobility management [1]. Since MIPv6 only support global mobility, a hierarchical scheme that separates micro-mobility from macro-mobility is preferable. In HMIPv6 the usage of MAP is to enhance the performance of Mobile IPv6 while minimising the impact on Mobile IPv6 or other IPv6 protocols. A MAP is essentially a local HA situated in the foreign network as shown in Fig. 1. It can be located at any level in a hierarchical network of routers so that the MN can send local binding update to the local MAP rather than the HA.

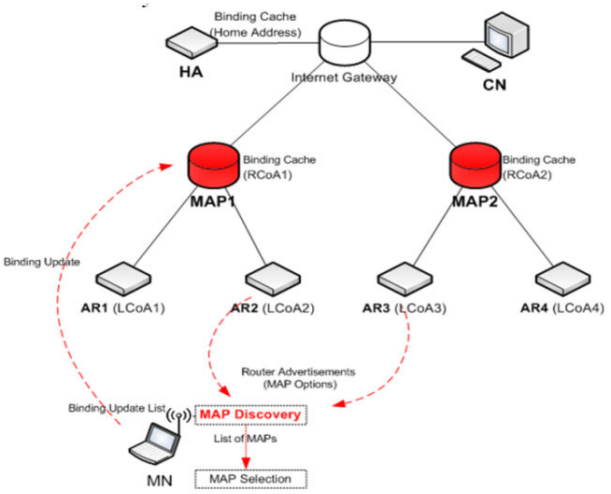


Fig. 1 HMIPv6 Operations

MAP Discovery should choose to use HMIPv6 implementation if the MN is HMIPv6-aware. Besides the uses of MAP in HMIPv6, an MN will also have to configure two new types CoAs: a regional care-of-address (RCoA) and an on-link care-of-address (LCoA). The LCoA is a local address to the MN received from Access Router (AR). The RCoA is an address on the MAP's subnet, configured when an MN received a Router Advertisement (RA) message with the MAP

Option during MAP Discovery. The MAP performs the function of a "local" HA that binds the MN's RCoA to an LCoA. After an MN get new RCoA and LCoA addresses then it sends a Local Binding Update (LBU) to the MAP in order to establish a binding between the RCoA and LCoA.

*A. Local Binding Update (LBU)*

When an MN enters a new MAP domain, it will receive RA containing information about one or more local MAPs. During RA, an MN will also detect whether it's still in the same MAP domain. If the MAP domain is different it needs to have two addresses from AR (LCoA and RCoA) otherwise only the LCoA will change. The MN can bind its current location (LCoA) with an address on the MAP's subnet (RCoA). The MAP will receive all packets on behalf of the MN it's serving and will encapsulate and forward them directly to the MN's current address. If the MN changes its current address within a local MAP domain, it only needs to register the new LCoA with the MAP. Hence, only the RCoA needs to be registered with CNs and the HA. The RCoA only change when the MN moves into different MAP domain. This makes the MN's mobility transparent to CNs it communicates with and also faster LBU compared to MIPv6.

*B. MAP Selection Scheme and MAP discovery*

The process of MAP Discovery continues everytime the MN received RA including a MAP option and it should start register with any new MAP through Neighbour Discovery [3]. The MN needs to consider several factors to optimally select one or more MAPs, where several MAPs are available in the same domain. During this MAP selection, it will be selected that is most distant or furthest, provided that its preference value and valid lifetime did not reach a value of zero. The discovery phase will also inform the MN of the distance of the MAP from the MN and store in a MAP Option. An MN should register with the MAP having the highest preference value. A MAP with a preference value of zero should not be used for new LBU. Also a MAP option with a valid lifetime value of zero indicates a MAP failure and when it's received, an MN must choose another MAP and create new bindings. If no other MAP is available, the MN must not attempt to use HMIPv6 [2].

## III. Related Works

In designing MAP selection scheme, characteristics of the MAP, MN and the network topology need to be identified and discussed [16] An MN needs to consider these elements when selecting the new MAP. Without an efficient MAP selection scheme will be seriously degrade the network performance and supporting seamless handover. Numerous researches have been carried out to deal these issues such as distance based, mobility based, adaptive based and dynamic based [6] [7] [8] [9]. In designing the scheme, the criteria of the MAP, MN, CN and network architecture need to be included. A technique such as load balancing or load control can be adapted to solve overload problem [4]. Pack *et al.* [5] has conducted a comparative study for the above MAP selection schemes. Overall, the mobility-based and the adaptive MAP selection schemes achieve more desirable performances than the distance scheme (the furthest and the nearest schemes). Also, the adaptive MAP selection scheme performs better in terms of load balancing than the mobility-based MAP selection scheme.

*A. Distance-based MAP Selection Scheme*

In HMIPv6, a distance-based selection was recommended where an MN may choose the furthest MAP in order to avoid frequent re-registrations [2]. The process will repeat until the MN find the valid lifetime with a preference value of the MAP. This algorithm is suitable for fast MNs that will perform frequent handoffs, because the fast MNs will reduce the probability of changing the serving MAP and informing HA and CNs of this change. Although HMIPv6 tries to improve the binding update between local MAP and CN, it creates the complexity of network management because of more of network entity such as MAP and additional address and LBU process. The scheme also creates a bottleneck as the site grows larger since the corresponding MAP suffers from the overload due to the increased data traffic to be tunnelled as well as BU signalling. During this, registering with the furthest MAP will increase the registration delay because the hop distance between the MN and the furthest MAP is comparatively larger than that between the one and the closer MAP. The preference value set in HMIPv6 is also a static 4 bits integer and no specific procedure to set up the characteristic.

*B. MAP Load Control Mechanism*

In previous research for MAP selection scheme, many adjusting algorithms and techniques adapted to solve load control problem. Most existing work focuses on load control or control mechanism from the view of MNs. The MN mobility properties such as velocity and speed are deployed to reduce and relieve MAPs overloaded.

In [16] introduced a load balancing mobility management by average BU interval in both AR and MN is adopted. When the interval of sending BUs in MN is shorter than that of receiving BUs in AR, the MN selects a MAP with largest distance because the MN's movement is estimated to be fast. If the interval of sending BUs in MN is longer than that of receiving BUS in AR, the MN selects a MAP with the second largest distance. To keep the transparency to HMIPv6, this average BU interval in AR is mapped into the 4-bit binary preference value in the MAP option.

Ito and Atsumi [17] proposed a scoring method to select a MAP and to achieve load balancing. The score is calculated from the historical handover frequency and the holding time value. Each MAP holds the management list of MNs sorted by the score. Then the MAP compares the load with another MAP by requesting the management of MN. The request is to manage MN with the smallest and the highest score on a list until load becomes balanced. In another mechanism, Wang *et al*. [13] designed the MAP Load Table (MLT) to record the load condition of neighbor MAPs. The scheme will choose the MAP which has minimum load value to register. The mechanism takes the MN's particular characteristics which include the mobility velocity and quantity of communication services.

*C. Velocity-based (Speed) Mechanism*

In order to speed up the handover between MAPs and reduce packet loss, an MN should send a LBU to its previous MAP, specifying its new LCoA. Packets in transit that reach the previous MAP are then forwarded to the new LCoA. In a scenario where several MAPs are discovered by the MN in one domain, it may need sophisticated algorithms to be able to select the appropriate MAP. These algorithms would have the MN speed as an input (for distance-based selection) combined with the preference field in the MAP option [2].

In velocity-based mechanisms [10] [13] there are two main steps: the measurement of the MN's velocity or speed and the selection of MAP to register with.The issue is how to measure the MN's speed because it is difficult to calculate the precise value of the speed. Only when the MN's speed is estimated and then the MN can select suitable MAP by the MAP Table (MT) that records the mapping relation between the MN and related MAP. Algorithms based on the speed of an MN, measured in handovers per unit time, were suggested in Kawano *et al*. [11] Faster MNs select more distant MAPs, as it is believed that faster movement leads to a larger moving area. Then, the estimated speed of the MT can be also obtained by dividing the distance that the MT has traversed in the previous access area by the dwell time.

Joe and Lee [12] proposed a selective MAP binding scheme that reduces the number of unnecessary local BU process in the MIPv6 based networks where the MN moves at high speed. Chung and Lee [14] proposed MAP selection schemes for HMIPv6 networks: LV-MAP and DV-MAP. These two proposed schemes select an optimal MAP and the furthest MAP supporting MN's velocity, with the aim to reduce the frequency of inter-domain handovers. The MN may need sophisticated algorithms to select the appropriate MAP and its speed as an input combined with the preference field (load control value) in the MAP option during RA

## IV. DMS_DLC Scheme

*A. Proposed Model*

A model integrates dynamic load control and speed detection mechanism to Distance-based MAP selection scheme which will support modularity. A few fields are introduced to MAP List (ML) as shown in Table I. The value of field preference in MAP Option will be replaced by the load calculated from ML. In this model consist of MAP discovery process, MAP selection scheme and load control mechanism, speed detection, binding update procedure and handover process. The MAP discovery process, binding update procedure and handover process already described in the related works. In this study we only describe the proposed speed mechanism. Besides, the MAP selection mechanism also integrates with the MAP load control mechanism which improves the drawback of Wang *et al*. [13].

TABLE I
MAP LIST (ML)

| MAP ID | Global Address | Preference Value | Valid Lifetime | Current Load | Maximum load | Threshold | Level in the hierarchy |
|---|---|---|---|---|---|---|---|
| IP | IP | 4 bits | 32 bits | 8 bits | 8 bits | 8 bits | 4 bits |

*B. DMS-DLC Algorithm*

The proposed algorithm in Fig. 2 will select the most suitable MAP with distance criteria and highest preference value. Information of all MAPs is collected form MAP Options for the purposed of selecting suitable MAP. Priority will be given to the furthest MAP with lowest load. The lower the distance will be the higher preference value. By this mechanism the MAP option for each MAP will continues updating to achieve a dynamic load control mechanism [18].

The current load and preference value are given as:

$$Current\ load = number\ of\ MAP\ Binding\ Cache \quad (1)$$

$$Preference = (1- (current\ load / threshold\ value)) * 15 \quad (2)$$

From the (2), the current load is inversely proportioned preference value. In this selection scheme the process will select the nearest MAP with highest preference where the maximum value is 15 in the MAP option.

*C. MN Movement and Speed Detection Algorithm*

We also suggest a model that detects the speed of the MN [19]. The process starts with the determination of the first location to the MN's next location. The speed of the MN will be calculated by the MN with the distance value divides by the time taken during the movement between locations. The process for the speed detection can be done during the handover of the MN to the new MAP. The MNs can select the furthest and nearest MAPs by according to their speed. The fastest MNs select the most distant MAPs and vice versa. The MN also can also change the scheme dynamically whenever the speed is changed soit will reduce frequent BU. In Fig. 2 the algorithm will determine the MN speed derived from the distance and time during each movement or after receiving successful Binding Acknowledgement (BA). It can dynamically change the nearest or furthest scheme depending of the current average speed.

The format of data movement is consists with value of column (m), row (m) and time (sec). If the MN moves from current location to destination location with n movement then the input data will be n. The input will be the MN's movement from current location to destination location:

$$mv_0 (x_0, y_0, t_0) \rightarrow mv_n (x_n, y_n, t_n) \quad (3)$$

where $mv_n$ is the movement of the MN $x_n$ and $y_n$ are destination coordinates of $x$ and $y$; and $t_n$ is destination time arrived in second. So the distance and time between current location to destination location are measured by;

$$Distance_n^2 = (x_n - x_{n-1})^2 + (y_n - y_{n-1})^2 \quad (4)$$

$$Time_n = t_n - t_{n-1} \quad (5)$$

The total of overall distance of the MN can be measured with the sum of all movement from 0 to n:

$$total\ distance = \sum_{n=0}^{\infty} \sqrt{((x_n - x_{n-1})^2 + (y_n - y_{n-1}))^2} \quad (6)$$

where $x_2$ and $y_2$ are the coordinate of MN's new location and $x_1$ and $y_1$ are the coordinate of MN's previous location while $t_n$ are $t_{n-1}$ are destination time and arrival time.

From (4) and (5) then the of MN's speed in second(s) can be derived:

$$speed_n = (distance_n / time_n)\ mps \quad (7)$$

$$average\ speed(n) = \sum_{n=0}^{\infty} \left(\frac{speed_n}{time_n}\right) / n \quad (8)$$

```
MAIN( )
Begin
    If MN is HMIP6-aware then
        Start Speed_Detection (Distance Scheme)
        MAP_Selection (DMS_DLC, Distance Scheme).
        /* Start Binding Update Process*/
         Binding Update (MAP)
         If MN receives rejected binding update
          repeat MAP_Selection( )
         else
          Process handover at new MAP
          The MN will release previous binding.
          Handover procedure is completed
         Endif
         /* After Successful Binding Update */
          Update load in ML and MAP options in new MAP and previous MAP
Else
     Exit()
End

Procedure Speed_Detection(Distance Scheme)
Begin
Record the new location new arrival time after receive successful BA from MAP
Calculate the distance = new location- previous location(meter)
Calculate the time = new arrival time- previous arrival time(ms)
Calculate the new speed = distance(m )/ time(s)
Update  previous location=new location,
   previous arrival time= previous arrival time
Define the speed of MN whether slow or fast
End
If speed = fast then return (Furthest MAP)
  elseif speed = slow then return(Nearest MAP)
End if
```

Fig. 2 DMS-DLC Algorithm

## V. Performance Analysis

We evaluate the performance of the DMS_DLC scheme in the context of MAP selection . The scenario was designed by the reason of IPv6 deployment challenges especially for the implementation in the real world scenario. The network scenario is shown in Fig. 3 and the relative parameters, in which the MN is moving across eight ARs in a two MAP domains where each domain contains three MAPs.

### *A. Experimental Setup*

In the simulation model, the scenario area is 2000×1250 meter$^2$ and the wireless diameter is within the range 200 meter. The total of ten MNs are communicated with the CNs through several of speed from slow to fast movement as shown in Fig.4.

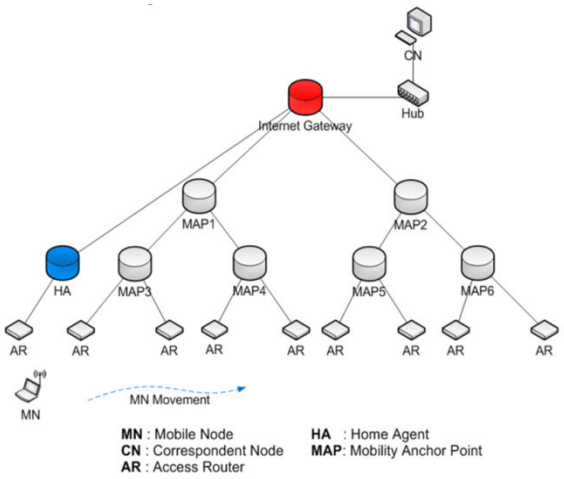


Fig. 3 Network scenario

The traffics are running on a ping application with 56 Bytes data and 5 seconds interval time. The wireless access network is based on the IEEE 802.11b and WLAN standard with a free space channel model. For the evaluation purpose we simulate three performance metrics: load condition of each level MAP, binding update cost and ping time or round-trip time (RTT) by each MN. Besides, the proposed scheme will also be compared with the other schemes: distance-based and dynamic based. The performance of the proposed scheme is evaluated by the network scenario of simulation using OMNeT++ [20].

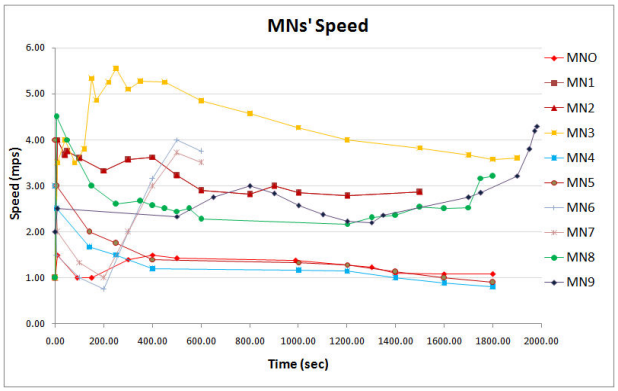


Fig. 4 MN's speed

### *B. Results*

As explained in related works the furthest scheme is proposed to reduce frequent handover but it is known that the highest level MAP has largest overloads. Hence, undoubtedly, the binding cache of each MAP can indicate the performance of MAP load control mechanism. Based on this observation, we define the total MAP binding cache (BC) as follows:

$$BC_{MAP_i} = \sum_{n=1}^{\infty} (BU_{MN_n}) \quad (9)$$

where $BU_{MN_n}$ is the binding update done by MNs to each MAP, respectively.

Fig. 5 shows the load distribution of each MAP by four different schemes. Although the total binding cache of proposed scheme is higher than the furthest, it still supports the best

distribution of MAP load. By comparing load for each level of MAP, the DMS_DLC reduces the higher level for the furthest scheme while for nearest scheme it reduces the lower level.

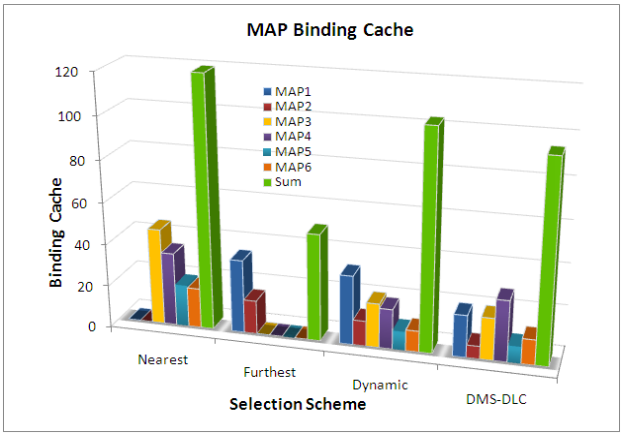


Fig. 5 Load Comparison between MAPs

*For MN we define binding update (BUL) list as follows:*

$$Total\ BUL_{MN_i} = \sum_{n=1}^{\infty}(BU_{HA_n}) + \sum_{n=1}^{\infty}(BU_{MAP_n}) + \sum_{n=1}^{\infty}(BU_{CN_n}) \quad (10)$$

where $BU_{HA_n}$, $BU_{MAP_n}$ and $BU_{CN_n}$ are weight values for the HA binding update, the MAP binding update , the CN binding update, respectively. Fig. 6 illustrates the performance of MN's binding update list within the schemes. It is obvious to discover that the proposed scheme can reduce the total binding update list.

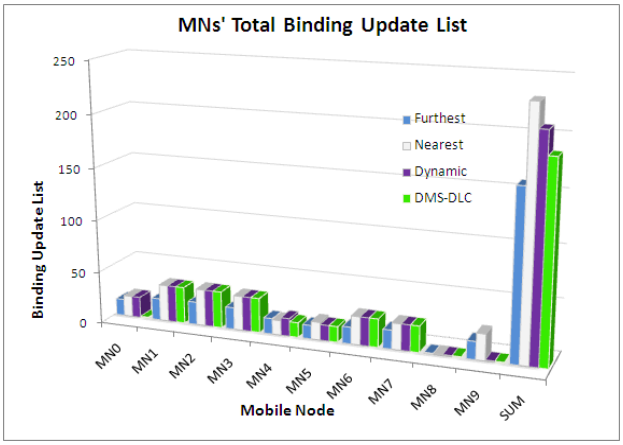


Fig. 6 Total MN's binding update list

*Also in ping application, the RTT was originally estimated in TCP by:*

$$RTT = (\alpha * Old\_RTT) + ((1 - \alpha) * New\_Round\_Trip\_Sample) \quad (11)$$

where $\alpha$ is constant weighting factor($0 \leq \alpha < 1$).

Fig. 7 depicts the performance ping RTT between four different schemes. It discovers that the DMS-DLC scheme can reduce the signal time for sending packet amongst the compared schemes. Hence, the scheme shows the best result of RTT by the MNs.

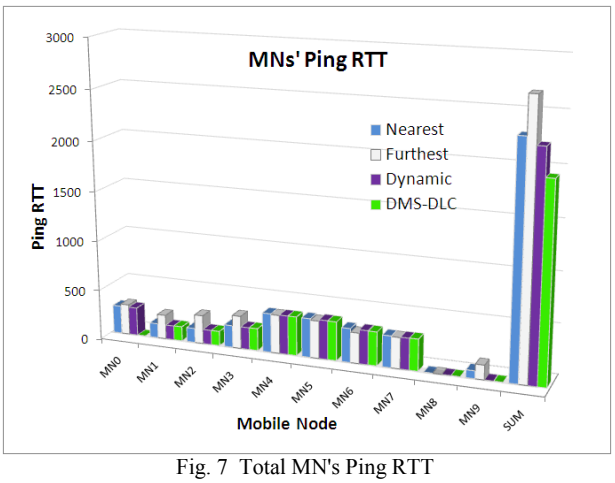


Fig. 7 Total MN's Ping RTT

## VI. Conclusion

There's significant needed of very sophisticated mobility protocols to support NGN QoS requirements and high speed handover. HMIPv6 protocol is one that will be support the NGN technology development for micro-mobility or Localized Mobility Management [15]. Previous works show that load control can reduce MAPs overload. This overload is due to the increased data traffic to be tunneled as well as BU signaling and maximum number of MN connected. In this study, we discussed and proposed the speed mechanism adapted in HMIPv6 MAP selection scheme. The load control and speed was measured based on MAP and MN properties. From the experimental results shows that our proposed scheme gives better distribution in MAP load and reduces binding update cost. In future, some mechanisms may be defined to allow MAPs to be discovered dynamically. Our future work will include analysis of MAP selection scheme using load control technique with multiple speed of MN and new attributes with study on distance based algorithms using dynamic load control.

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