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Handoff scheme to enhance performance in SIGMA

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***Abstract*—Mobile Internet Protocol(MIP), an industry standard for handling mobility, suffers from high handover latency and packet loss, in addition to change in network infrastructure. To overcome these problems, we proposed a new approach called Seamless IP diversity based Generalized Mobility Architecture (SIGMA). Although SIGMA achieved a low latency handoff, use of IP diversity resulted in some instability during handoff. In this paper, we propose a new handoff policy, called HANSIG-HR, to solve the instability problem of SIGMA. HANSIG-HR is based on Signal to Noise Ratio (SNR), hysteresis and route cache flushing. Our experimental results show that HANSIG-HR improves the stability of SIGMA.**

Keywords: Hand off Latency, MIP, SIGMA, Throughput, SNR, HANSIG, HANSIG-H,and HANSIG-HR.

I. INTRODUCTION

Mobile IP Perkins [1] is the standard proposed by IETF to handle mobility of Internet hosts for mobile data communication. Mobile IP suffers from a number of problems, such as high handover latency, high packet loss, and requires change in network infrastructure. To solve these problems, we are earlier proposed a transport layer based mobility management scheme called Seamless IP diversity based Generalized Mobility Architecture (SIGMA). SIGMA exploits multiple addresses available to most mobile hosts to perform a seamless handoff. Stream Control Transmission Protocol (SCTP) [2], a transport layer protocol being standardized by IETF was used to validate and test the concepts and performance of SIGMA. Use of multiple interface cards in our previous studies on SIGMA, resulted in some instability during handoff due to the handoff latency. The instability was due to of excessive number of handoffs in the overlapping region.

There are previous work on reducing number of handoffs and handoff latencies for Cellular IP, Mobile IP, and Layer 2 handoffs. For example, work on Cellular IP [3], [4] used average receiving power, receiving window, bit error ratio and signal strengths. Portoles et al. [7] reduced Layer 2 handoff latency by using signal strength and buffering techniques. Aust et al. [8] used Signal-to-Noise Ratio for Mobile IP handoffs. It should be noted the above work deal with either link layer handoffs, or are designed for specific architectures (like cellular IP and Mobile IP). The authors are not aware of any work which studied handoff schemes for transport layer based mobility management schemes.

The objective of this paper is to remove the instability observed in previous studies of SIGMA by proposing a handoff scheme for SIGMA. Initiation of handoff, also known as handoff trigger, is a crucial part of any handoff policy. Signal-to-Noise Ratio, Signal-to-Interference Ratio, Bit-Error-Rate and Frame Error Rate (FER) are generally used for link layer handoff triggers [9]. Since our experimental environment has noise and negligible interference, we use Signal-to-Noise Ratio (SNR) as the handoff trigger in our proposed handoff policy of SIGMA. We designed three HANdoff schemes for SIGMA, (i) HANSIG, with SNR alone, (ii) HANSIG-H, with SNR and Hysteresis and (iii) HANSIG-HR, with SNR, Hysteresis and Route cache flush. Results from experimental testbed of SIGMA are collected for these three schemes and compared.

The rest of this paper is organized as follows. Sec. II is a brief introduction to SIGMA. Instability of SIGMA, the motivation for this work, is illustrated in Sec. III. Previous work on handoff schemes, their methods, advantages, and disadvantages are described in Sec. IV. Our proposed handoff scheme is described in Sec. V. Experimental setup for testing proposed handoff schemes is described in Sec. VI, followed by experimental results and concluding remarks in Secs. VII and Sec. VIII, respectively.

II. INTRODUCTION TO SIGMA

SIGMAis a transport layer based seamless handoff scheme which is based on IP diversity offered by multiple interfaces in mobile nodes to carry out a soft handoff. Stream Control Transmission Protocol's (SCTP) multi-homing feature is used to illustrate the concepts of SIGMA. SCTP allows an association (see Fig. 1) between two end points to span multiple IP addresses of multiple network interface cards. Addresses can be dynamically added and deleted from an association by using ASCONF chunks of SCTP's dynamic address reconfiguration feature [2]. One of the addresses is designated as the primary while the others can be used as a backup in the case of failure of the primary address. In Fig. 1, a multi homed Mobile Node (MN) is connected to a Correspondent Node (CN) through two wireless networks. The various steps of SIGMA(see Fig. 1) are given below.

1) STEP 1: **Obtain new IP address***:* The handoff procedure begins when the MN moves into the overlapping radio coverage area of two adjacent subnets. Once the MN receives the router advertisement from the new access point (Access Point 2), it should initiate the procedure of obtaining a new IP address (IP2 in Fig. 1).

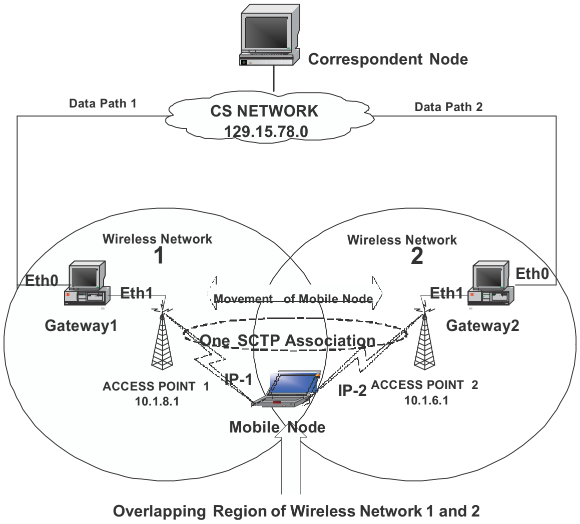


Fig. 1. Experimental testbed.

2) STEP 2: **Add IP addresses to association***:* When the SCTP association was initially setup, only the CN's IP address and the MN's first IP address (IP1) were exchanged between CN and MN. After the MN obtains another IP address (IP2

In the meantime, a large number of Set Primaries are issued

in STEP 1), MN binds IP2 into the association (in addition to IP1), and notify CN about the availability of the new IP Address

3) STEP 3: **Redirect data packets to new IP address:** When MN moves further into the coverage area of Wireless Network 2, Data Path 2 becomes increasingly more reliable than Data Path 1. CN can then redirect data traffic to IP2 to increase the possibility of data being delivered successfully to the MN. MN accomplishes this task by sending an ASCONF chunk with the Set Primary Address parameter, which results in CN setting its primary destination address to MN as IP2. The MN's routing table is also changed so that packets leaving MN are routed through IP2.

4) STEP 4: **Updating the location manager:** Location management of SIGMA is implemented by a location manager that maintains a database of correspondence between MN's identity its current primary IP address. MN can use any unique information as its identity, such as the home address

(as in MIP), domain name, or a public key defined in the Public Key Infrastructure (PKI).

5) STEP 5: Delete or deactivate obsolete IP address: When MN moves out of the coverage of Wireless Network 1, no *new* or *retransmitted* data packets are directed to IP1. MN notifies CN that IP1 is out of service for data transmission by sending an ASCONF chunk to CN. Once received, CN deletes IP1 from its local association control block and acknowledges to MN indicating successful deletion.

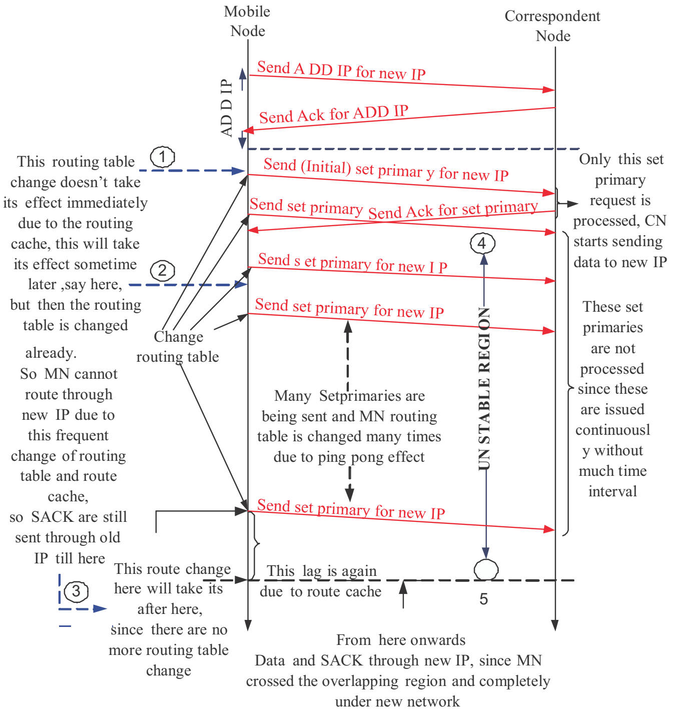
The actual handoff takes place in Step 3; the handoff scheme for SIGMA has to consider the exact time at which MN should send Set Primary, the objective being to reduce the number of

III. INSTABILITY OF SIGMA

In this section, we illustrate the instability of SIGMAusing the timeline shown in Fig. 2. When MN moves between regions of the wireless networks it is in one of the two states: (i) Stable state is where the MN receives data and sends SACK through same IP address; (ii) Unstable state where the MN receives data through one IP address and sends SACK through another IP address. In SIGMA each Set Primary sent.

Sec. II-.3). In Fig. 2, Indicates the time where the initial Set Primary is being sent from the MN to the CN during handoff. This Set Primary request will be processed by the CN, and CN will start sending data to the new IP. At the same time, the MN will change its routing table but it will take its effect only during 2 due to route cache (see Sec.V). and the routing table is changed due to ping pong effect. So even at 2 of Fig. 2, the MN might not route through the new IP, since routing table has already changed. So MN will send SACKs through old IP when CN sends data to new IP. Moreover after the initial Set Primaries, the subsequent Set Primaries requests are ignored by the CN, because of many Set Primaries arriving in a short interval of time. So, only at

3 , the last routing table change will have its effect, and the data and SACK both will go through new IP. Therefore we call the time from 4 to 5 as Unstable State, where the MN uses one IP to receive data and another IP to send SACK.



handoffs and avoid instability.

Fig. 2. Timeline for SIGMA explaining the unstable region.

To illustrate the instability of SIGMA in real data transfer, we use Fig. 3 that shows the throughput of SIGMA in our experimental setup (given in Sec. VI) with HANSIGscheme.

Fig. 3 shows the throughput as a function of time. The figure is divided into five regions representing that the MN alternates between the stable and unstable states as given below.

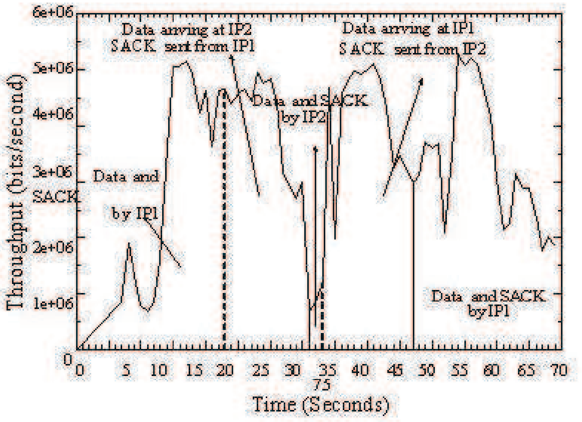


Fig. 3. Throughput for the HANSIG.

1) From time 0 to 23 seconds, the MN is in Wireless Network 1 during which data are received and SACK are sent through IP1; this is the stable state for MN.
2) From 23 to 36 seconds, MN is in unstable state, where data are received from IP2 and SACKs are sent from IP1 which is due to excessive number of handoff and route cache.
3) After MN enters Wireless Network 2 completely, where the MN is again in stable state.
4) When MN moves back from Wireless Network 2 to Wireless Network 1, it is in an unstable state between 38 to 52 seconds.
5) From 52 seconds, the MN is completely under Wireless Network 1 and in the stable state.

We can see from Fig. 3, the MN is in unstable state for a longer period, which is due to the number of Set_Primaries that are being sent to the CN (discussed in Sec. II) because of a large number of handoff and due to the route cache (see Sec. V).

The unstable state for SIGMA can also be called handoff latency, because for other schemes, such as Mobile IP which uses single interface, handoff latency has been defined in previous work as the time taken by the MN to completely switch from between networks. In SIGMA the MN is completely under the new network, i.e., uses new IP for both data and SACK, only after the unstable state. So our aim is to reduce the time during which MN is in unstable state, thus reducing the handoff latency. Reducing the unstable state is important because packet losses will occur if an access point becomes unavailable while MN is using both interfaces. We remove this unstable state by using an efficient handoff scheme. In the next section, we discuss previous work on reducing handoff latency.

IV. PREVIOUS WORK

One of the first work to reduce the number of handoffs [9] describes various criteria that can be used to trigger Layer 2 handoffs. The criteria include Relative Signal Strength (RSS), RSS with Threshold (*T*), RSS with Hysteresis (*H*) and RSS with Threshold (*T*) and Hysteresis (*H*). There are many previous work on reducing the handoff latency. Most of them depend on architectural features such as Mobile IP, Cellular IP etc. Hua et al. [10] have designed a scheme for Mobile IP which makes use of concept called Multi-tunnel where the HA copies an IP packet destined to the MN and sends them to multiple destinations through multi-tunnel.

Belghoul et al. [10] present pure IPv6 Soft Handover mechanisms, based on IPv6 flows duplication and merging in order to offer pure IP-based mobility management over heterogenous networks by using Duplication & Merging Agent (D&M). In Polimand (Policy based handoff policy) Aust et al. [7] reduce handoff latency to accelerate the handoff process through a combination of MIP signaling and link layer hits obtained from General Link Layer.

Portoles et al. [7] try to reduce Layer 2 handoff latency by buffering Layer 2 in the driver and card of the AP1 and forwarding them to AP2. Shin et al. [11] reduce the MAC layer handoff latency by selective scanning (a well-selected subset of channels will be scanned, reducing the probe delay) and caching (AP built a cache table which uses the MAC address of the current AP as the key).

RSS and BER based algorithms have been reported by Chia et al. [5] for Cellular IP. They compiled a radio propagation and BER database for handover simulation in typical city microcellular radio systems, so as to provide realistic data for handover simulation, thus minimizing inaccuracies due to inadequacies in propagation modeling.

Austin et al. [4] studied velocity adaptive algorithm for Cellular IP. They use average receiving power, i.e., calculate signal strength time averages from *N* neighboring base stations and reconnect the mobile subscriber to an alternate BS whenever the signal strength of the alternate BS exceeds that of the serving BS by at least *H* dB.

As discussed above, most of the previous work focused on techniques to reduce the number of handoffs and handoff latency. The techniques used to reduce number of handoffs [9] can be applied to SIGMA, since SIGMA can get the Layer 2 information.

However previous work to reduce the latency per handoff is not applicable to SIGMA because, work such as [5], [11] are for reducing handoff latency at Layer 2, whereas SIGMA is based at Layer 4. Other work such as [9], [10] are based on architectures like Mobile IP and Cellular IP which are different from SIGMA architecture.

Considering the above facts, we develop our own handoff scheme to avoid to enhance stability in SIGMA by making use of the architectural features of SIGMA.

V. HANDOFF SCHEME TO ENHANCE PERFORMANCE IN SIGMA

The instability of SIGMA described in Sec. III depends on two factors:

1) Fluctuation of signal strength, which increases the number of handoffs due to ping pong effect. Ping pong

effect can be reduced by using one of the techniques to reduce number of handoff as discussed in Sec. IV.

2) Route cache effect, where the kernel first searches the route cache for a matching entry for the destination of a packet, followed by search in the main routing table (also called Forwarding Information Base (FIB)). If the kernel finds a matching entry during route cache lookup, it forwards the packet immediately and stops traversing the routing tables. Because the routing cache is maintained by the kernel separately from the routing tables, manipulating the routing tables may not have an immediate effect on the kernel's choice of path for a given packet.

We use IP route flush cache to avoid a non-deterministic lag between the time that a new route is entered into the kernel routing tables and the time that a new lookup in those route tables is performed. Once the route cache has been flushed, new route lookups (if not by a packet, then manually with IP route get) will result in a new lookup to the kernel routing tables.

Our proposed handoff scheme, called HANSIG-HR is designed to remove both the ping pong and route cache effects as described below.

HANSIG-HR: Our proposed HANSIG-HR scheme makes use of Signal-to-Noise Ratio (SNR) (discussed in Sec. I), hysteresis to reduce the number of handoff (discussed in the Sec. IV), and route cache flush (discussed in Sec. V). The pseudo code for HANSIG-HR is given below, where SNR1 and SNR2 are the Signal to Noise Ratios of AP1 and AP2, respectively, and Hysteresis is the hysteresis value.

```
while(1) {
Calculate SNR1 = (SignalStrenth/NoiseStrength) for AP1
Calculate SNR2 = (SignalStrenth/NoiseStrength) for AP2
If (SNR2 > SNR1) and (SNR2 - SNR1 > Hyst)
Issue Set\_Primary to set IP2 as primary address in CN
If (SNR1 > SNR2) and (SNR1 - SNR2 > Hyst)
Issue Set\_Primary to set IP1 as primary address in CN
Change routing table of MN and flush route cache
}
```

The pseudo code for HANSIG and HANSIG-H is similar to HANSIG-HR, but for HANSIG-H there is no flush route cache. Similarly for HANSIG, the Hysteresis value is zero and there is no flush route cache.

Optimum value of Hysteresis: Based on signal strength fluctuations, we now determine an optimum hysteresis value. Fig. 4 shows the variation of SNR, as measured in our testbed, as the MN moves at a uniform speed from Wireless Network 1 to Wireless Network 2. In Fig. 4, we can see that the maximum difference between the access point's SNRs is 3 dB in the ping pong region. For example, if the hysteresis value is less than 3 dB, then many unnecessary handoff would have taken place between 45 and 46 seconds in Fig. 4. We, therefore, assigned a hysteresis value of 4 in our experimental test bed.

This HANSIG, HANSIG-H, and HANSIG-HR are implemented in the MN, and results are obtained using the experimental setup discussed in the next section.

VI. EXPERIMENTAL SETUP

The HANSIG, HANSIG-H and HANSIG-HR discussed in Sec. V was implemented in the testbed shown in Fig. 1. The testbed consists of MN, CN and gateways (used to form Wireless Network 1 and Wireless Network 2).

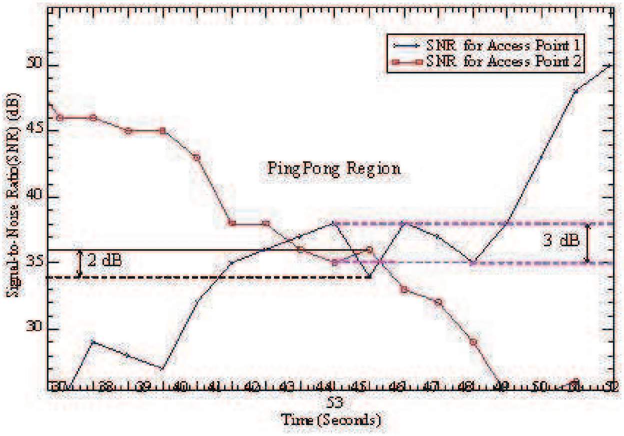


Fig. 4. Variation of Signal-to-Noise-Ratio (SNR) of the access points.

The gateways and CN are Dell Desktops running RedHat Linux 9 with kernels 2.4.20 and 2.6.6, respectively. The MN is a Dell-Inspiron 1100 Laptop with two wireless NIC cards (Avaya PCMCIA and Netgear USB wireless cards) running RedHat Linux 9 kernel 2.6.6.

VII. RESULTS FOR THE HANDOFF SCHEME

In this section, we present results to demonstrate the effectiveness of different handoff schemes we proposed using our experimental test bed described in Sec. VI. The effectiveness of handoff schemes of HANSIG, HANSIG-H and HANSIG-HR are presented and compared. We use throughput and handoff frequency as measures of effectiveness of our proposed handoff schemes.

A. Effect of hysteresis on number of handoffs

We observed the number of handoffs for different values of hysteresis. It was observed that for a hysteresis value of 0, 1, 2, 3 and 4, the average number of handoffs were 15, 11, 6, and 1, respectively. Therefore, for the rest of the results, we used a hysteresis value of 4.

B. Effect of hysteresis on data flow

The effect of hysteresis on the throughput of SIGMA is shown in Fig. 5 implementing HANSIG-H.

As shown in the Fig. 5, the graph is divided into five regions where the MN will be in these two states alternatively. From time 0 to 20.57 seconds, the MN is in Wireless Network 1 during which data are received and SACKs sent through IP1. From time 20.57 to 22.18 seconds, MN is said to be in unstable state, where the data are received from IP2 and SACKs are sent from IP1 due to the excessive number of handoff due to ping pong effect resulting from signal strengths variation. Between 22.18 to 73.97 seconds MN enters Wireless Network 2 completely, during which the MN is in stable state receiving data and sending SACKs through a single IP i.e., IP2. When MN moves back from Wireless Network 2 to Wireless Network 1, it again goes to unstable state; from time 74.97 to 75.50 seconds data are being received from IP1 and SACKs are sent from IP2, which is again due to the number of handoffs resulting from ping pong effect. The MN is then completely under Wireless Network 1 and is in stable state from 75.50 seconds onwards.

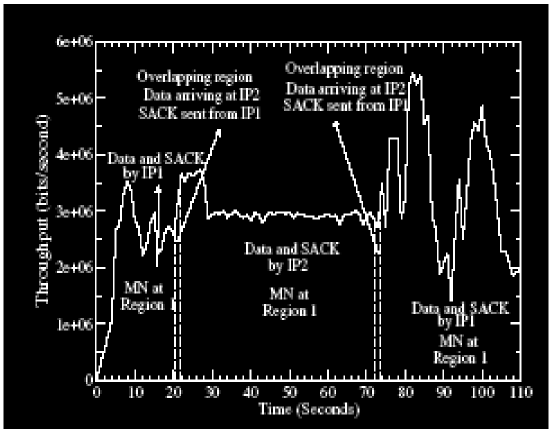


Fig. 5. Throughput for `HANSIG-H`.

The MN is unstable during the periods from 20.57 to 22.18 seconds and 74.97 to 75.50 seconds even with hysteresis implemented. The instability is due to the caching effect of the routing table, even though there was only one handoff.

C. Effect of hysteresis and route cache flush on data flow

The number of handoffs in the overlapping region and throughput were measured for HANSIG and HANSIG-HR. The throughput for the HANSIGis shown in Fig. 3. The durations of the unstable state are 5 seconds and 20 seconds. These are due to the excessive number of handoffs which have taken place without using the hysteresis, when the MN is in the overlapping region.

So we can see that the duration of time, for which the MN receive data from one IP and send SACK through another IP, depends on the number of handoff taking place, when MN moves between wireless networks. Packets will be lost if the MN loses contact with one of the access points during which the MN is using both interfaces (one for receiving data and another for sending SACK).

The throughput of HANSIG-HRis shown in Fig. 6 with only three regions: From 0 to 19 seconds, MN sends and receives data through IP1, from 19 to 39 seconds MN receives and sends data through IP2, and from 39 seconds onwards it receives and sends data through IP1. These three regions were identified by analyzing the ethereal captures during the data transfers. From this we can infer that at any point of time MN will always be in stable state.

We can, therefore, see that the MN is in unstable for a longer time when no hysteresis is used (Figs. 3) as compared to when hysteresis is used (Fig. 6) i.e. hysteresis and route cache flushing (HANSIG-HR) improves the performance of SIGMA.

VIII. CONCLUSION AND FUTURE WORK

We have proposed an new handoff policy for SIGMA, and analyzed the effect of the policy on enhancement of stability of SIGMA. We observed that the new handoff Policy HANSIG-HR, which is based on signal to noise ratio, hysteresis and route cache flush, significantly improved the performance of SIGMA. Future work consists of improving the handoff policy by using dwell timer, threshold, and dynamically determining the value of the hysteresis based on the characteristic of signal fluctuations.

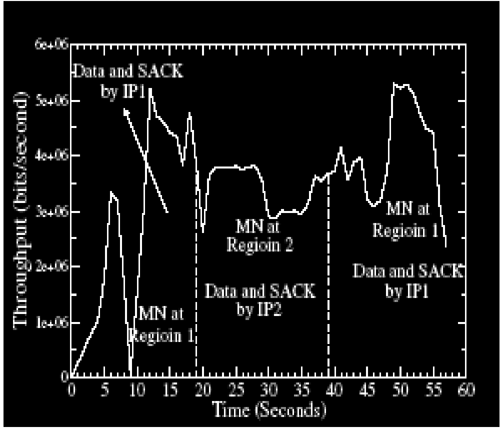


Fig. 6. Throughput for `HANSIG-HR`.

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