FAST MOBILE IPV6 APPROACH FOR WIRELESS LAN BASED NETWORKS

Link-Layer Triggering Support for IEEE 802.11

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Keywords: Mobile IPv6, Fast MIPv6, Wireless LAN, Link-Layer Triggering, Fast IEEE 802.11 Handover.

Abstract: The standard Mobile IPv6 specification provides comprehensive mobility management for the IPv6 protocol. During the handover there is a period in which the mobile node is unable to send or receive packets due to link-layer switching and IPv6 protocol layer operations. This overall handoff latency resulting from baseline MIPv6 procedures, namely movement detection, new care-of address configuration, and binding updates with peer entities, is often unacceptable for any kind of real-time service (video-conferencing, voice-over-IP,…). A new fast handover approach, based on Fast Handovers for Mobile IPv6, is proposed in this paper, which will support seamless movement in between IPv6 domains using a IEEE 802.11 network infrastructure. A new low latency handoff method for IEEE 802.11 will be proposed, where access point beacons are utilized for carrying IPv6 prefix information without altering the Mobile IP or IEEE 802.11 specifications. A WLAN service will continuously monitor the radio signal quality of the attached access point and, if necessary, will switch to another access point in range. This feature and the elimination of firmware-based active scanning during link-layer handovers have the flavor effect of reducing the overall link-layer handoff delay to about 10%. We will further introduce our wireless testbed infrastructure for evaluation of the proposed approach. Performance evaluation is used to verify the effectiveness of our implementation and an extensive simulative comparison is used for scalability analyses.

1 INTRODUCTION

Owing to the assistance of Mobile IPv6 (Johnson, 2004), a mobile node can effectively maintain its IP-layer connectivity to the Internet when it changes its point-of-attachment somewhere in the world. During the accomplishment of the handover, the mobile node is unable to send or receive IPv6 packets because of its L2 and also L3 handover operations. This high handover latency is unacceptable to real-time applications or delay sensitive traffic. Each time a mobile client moves, it is necessary to perform movement detection by discovering (sending router solicitation) its current point of attachment. In Mobile IPv6 (Johnson, 2004), the movement detection algorithm relies on the periodic sending of router advertisements in order to enable the mobile node to determine its current location. The only way to improve the detection performance is to broadcast router advertisements at a faster rate, which may result in a poor link utilization. For that reason the fast handover protocol (Koodli, 2004) is designed to achieve a seamless handoff when mobile nodes move from one domain to another.

In a mobile-initiated and anticipated fast-handover scenario described in (Koodli, 2004), the mobile node first sends a Router Solicitation for Proxy (RtSolPr) message to the current access router containing any Access Point specific identifiers. The current Access Router replies with a Proxy Router Advertisement (PrRtrAdv) message , which may contain a subnet-specific information tuple [AP-ID, AR-MAC, AR-IP]. This message exchange allows a mobile node to obtain the new Access Router's prefix information, which is needed to perform an “anticipative” configuration of the new IPv6 address on the new subnet. Figure 1 presents a general mobile-initiated “predictive” fast handover scenario.

Jordan N. and Poropatich A. (2004).
FAST MOBILE IPV6 APPROACH FOR WIRELESS LAN BASED NETWORKS - Link-Layer Triggering Support for IEEE 802.11.
In *Proceedings of the First International Conference on E-Business and Telecommunication Networks*, pages 102-108
DOI: 10.5220/0001395301020108

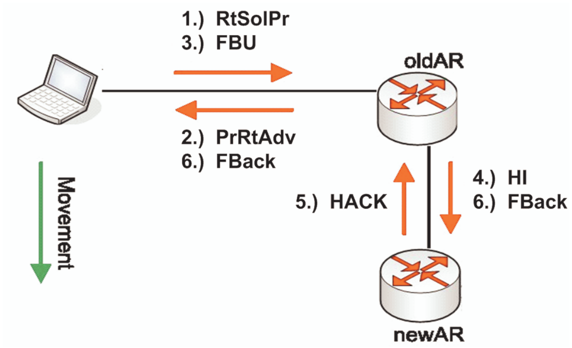

Figure 1: Reference Scenario for FMIPv6 Handover.

With the information provided in the PrRtAdv message, the MN formulates a prospective new CoA and sends a Fast Binding Update (FBU) message. The purpose of FBU is to authorize the old AR to bind the current Care-of address (CoA) to new CoA, so that arriving packets can be tunneled to the new location. Depending on whether an FBack (Fast Binding Acknowledgement) is received prior to the Mobile Node's movement or not, the prospective address can be used immediately after attaching to the new subnet link. In case it moves without receiving an FBack, the MN can still start using the new CoA after announcing its attachment through a Fast Neighbor Advertisement (FNA) message (see Figure 2).

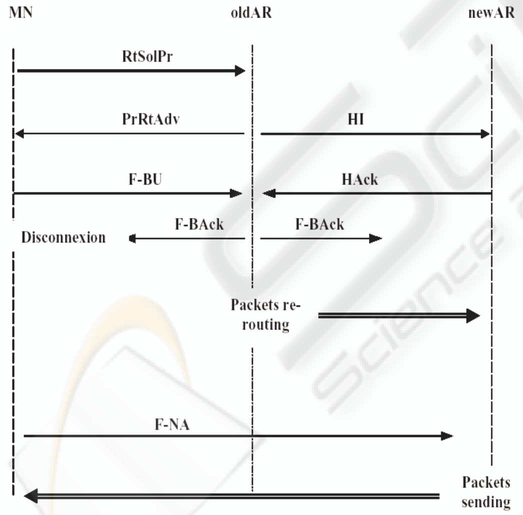

Figure 2: Message Flow for Mobile-Initiated HO.

However, the above protocol assumes that the L2 protocol is capable of delivering the L2 identifier of the new access point to the mobile node. More important, to initiate a seamless handover, is the fact that the current AR must be capable of mapping this new L2 identifier into the IP address of the target AR. We will show that all these requirements for Fast MIPv6 can be fulfilled in our implementation without any modifications to the IEEE 802.11 standards.

2 FAST HANDOVER FOR IEEE 802.11

The growing popularity of IEEE 802.11 (IEEE, 1999) has made "wireless" LAN a potential candidate technology for providing high speed reliable wireless access services. In addition by supporting Mobile IP, wireless LAN can meet demands for expanded wireless access coverage while maintaining continuous connectivity from one domain into another. In order to be able to accomplish a fast handover on Layer 3 it is necessary to implement a triggered information indicated by the underlying link-layer driver.

2.1 Link-Layer Triggering

In order to achieve an efficient interworking between Fast Mobile IPv6 and IEEE 802.11, it is necessary that the link-layer initiates the handover. The mobile node normally does this by sending a proxy router solicitation at the IP layer. This action is triggered by the underlying link layer in the mobile node, which must be aware that a handover is about to take place. This is the only possible way since from the IEEE 802.11 link-layer's point of view the mobile node is the only entity which is aware, that the host is about to attach to a new AP. In our implementation there is a tool running at the mobile node which continuously monitors the signal strength of the attached AP. In case the receiving power-level falls below a pre-defined value, the tool reacts by collecting information of all APs in range. So the tool is able to anticipate the best destination for the handover. At the same time of preparing the link-layer handover to the most qualified AP, the client-tool will send a trigger message to the fast-handover module. The next step that follows is the proposed FMIPv6 approach explained in Section 3.

2.2 Enhanced WLAN Handover

Even if the Fast Mobile IP approach is implemented properly, there are still delay issues to solve during the link-layer handover. Since Mobile IP and link-layer handover should go hand-in-hand, there is still an unsolved problem with the Layer 2 handoff-latency when the mobile node moves from one AP to another. There exists a definite period of time in which the mobile node is unreachable due to the layer 2 movement (i.e. re-synchronization with the new AP). It has to be remarked that the exact amount of time varies, depending on the deployed WLAN technology. Some measurements (Velayos, 2003) (Velayos, 2004) (Mishra, 2002) for IEEE 802.11b show that this time period can vary from 200 to 1500 ms, depending on the type of vendor equipment.

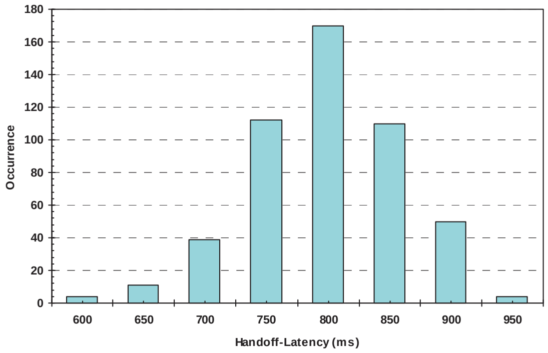

Figure 3: IEEE 802.11b HO Latency without Optimization.

The main problem during the handover is the fact that stations have to detect the lack of radio connectivity based on unsuccessful frame transmissions. The difficulty is to determine the reason for the failure among collision, radio signal fading or the station being out of range. In our implementation the signal strength is monitored continuously. In case that the signaling level drops below a predefined threshold, the tool automatically tries to handoff to an AP in range, which provides a much better connectivity. So the long phase of detection can be saved and the handover is carried out much faster. This WLAN handover-tool takes advantage of the information provided by the physical layer and completely skips the detection phase. Stations equipped with our tool start the search phase when the quality of the radio-signal falls below a pre-defined threshold. Therefore, the search always starts before any frame has been lost. This has the favorable effect that the overall handover-time can be reduced to about 350ms, as demonstrated in (Jordan, 2003). Another issue of WLAN is the active-scan process, which is often enforced with each AP-handover. Preventing active-scanning, additionally helps to reduce the link-layer latency to about 60 to 100 ms (depending on vendor hardware).

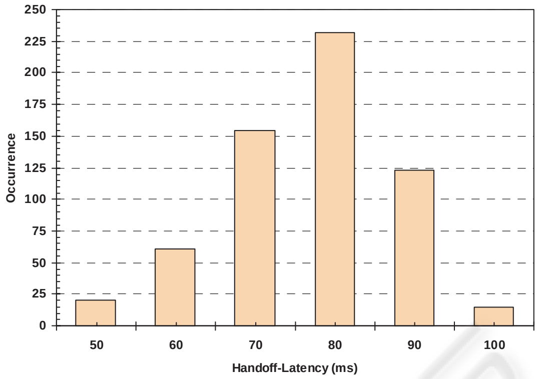

Figure 4: Optimized IEEE 802.11b Handover.

These initial improvements will enable wireless networks to carry real-time applications along the infrastructure.

3 PROPOSED FAST HANDOVER APPROACH

As already stated in Section 2 our implementation helps the Mobile Node to detect if the current link is degrading and therefore starts searching for a new AP with improved link-quality. To do this, the mobile node scans all possible frequencies (specified by the IEEE 802.11b standard) [10] and compares the received signal with the one currently received. If the mobile node finds a better signal it can switch to the new AP. But the mobile node's link layer implementation does not know whether this AP is attached to a new AR. The link layer only knows about link layer addresses and the AP's SSID (Service Set Identifier) string. However, if the AP name/link layer address (which identifies an AP) is known, the mobile node's IP-layer implementation can request that the current AR should provide the prefix/router address, which the new AP is attached to. This idea assumes that an AR is configured with a table containing its own and the neighboring APs link-layer addresses and their corresponding AR.

In our implementation we configure each access point involved with a special SSID string (e.g.: SSID = "2001:200:8:72AB:1434::1/64") which further implicitly presents all information about the prefix of the attached AR. Whenever the mobile node anticipates a handoff, the handover-tool exactly knows the prefix of the new AR the AP is attached to. In that way the mobile node performs "anticipative" configuration of the new IP address on the new subnet using the router prefix information carried in the beacon message of the new AP. If more than one destination access point is in range, the mobile node could prefer to carry out a movement to an AP within the same subnet. Thus only a link-layer handover would be performed, which further improves the handoff-latency in this special case. In all other cases the mobile node will perform the configuration of a new IP address and continues with the Fast Mobile IPv6 handover until the mobile node arrives at the new AR (NAR).

4 IMPLEMENTATION OVERVIEW

To make a serious network evaluation in the area of Mobile IPv6 possible, we implemented an enhanced IPv6 testbed which is connected to the worldwide native “6net” infrastructure. As it can be seen in Figure 5, we built up a central core network where all subnetworks are attached to. In between each included network provider, we implemented WAN-Emulators that thwart all IPv6 packets transmitted. As our major aim was to create a very flexible network infrastructure, we put a single WAN-Emulator for each provider. So we are able to tune the link-delay individually, depending on the appropriate scenarios to be analyzed. Wireless LAN IEEE 802.11b and IEEE 802.11g are deployed in the overall infrastructure.

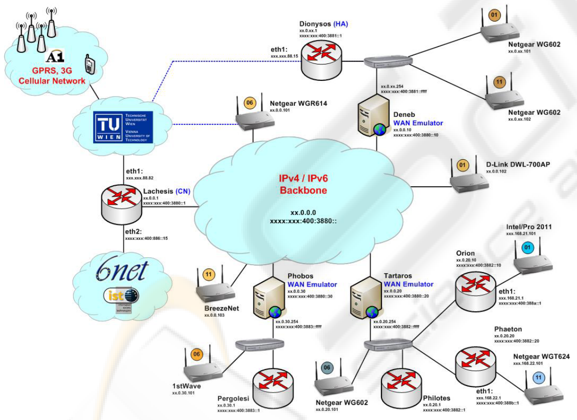

Figure 5: Mobile IP Testbed at TU-Vienna.

Three independent network operator domains were deployed, whereas one includes the Home Agent for the mobile node experiments. Furthermore, another network operator domain includes some kind of hierarchical structure in order to be able to do a performance comparison with the alternative HMIPv6 approach. All hosts including mobile nodes, correspondent nodes and the routers within each provider’s area have RedHat Linux 8.0 installed with Kernel 2.4.22. For the MIPv6 basis functionality we utilized MIPL 1.0, provided by Helsinki University of Technology (HUT).

The Linux driver for all WLAN activities is based on the HostAP project, which seems to be the most flexible environment for making link-layer triggering realizable in a very fast manner. HostAP provides a general Linux driver for all PRISM2/2.5/3 based Wireless LAN cards. The results of an initial link-layer trigger optimization can be seen in Figure 3 and 4. These measurements are deployed by skipping the active-scanning mechanism within each handover.

5 PERFORMANCE EVALUATION

In this section we present initial results for a verification of the implemented IPv6 mechanisms and furthermore results based on our real-world Mobile IPv6 network infrastructure. For all measurements we derived average-values from about 1000 samples for each point in the graphics. This helps us to get significant and serious results for comparing of standard Mobile IPv6 to the enhanced FMIPv6 approach.

The first graph presents the difference in between communication with and without Route Optimization. The results of the end-to-end delay, depending on various link-delays, are presented in Figure 6.

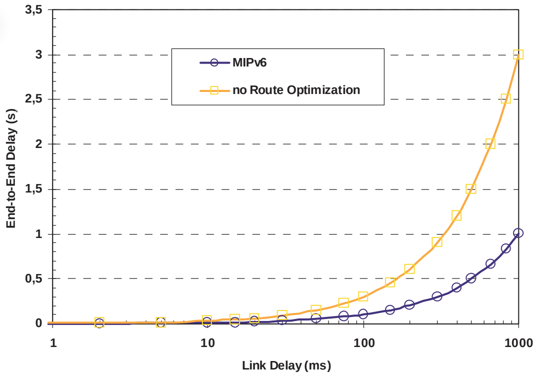

Figure 6: Route Optimization Impact on End-to-End Delay.

Figure 7 depicts the dependence of the handoff latency (foreign link – foreign link) on the variance of sending Router Advertisements. Obviously, the handoff latency falls off as Router Advertisement messages are sent more frequently.

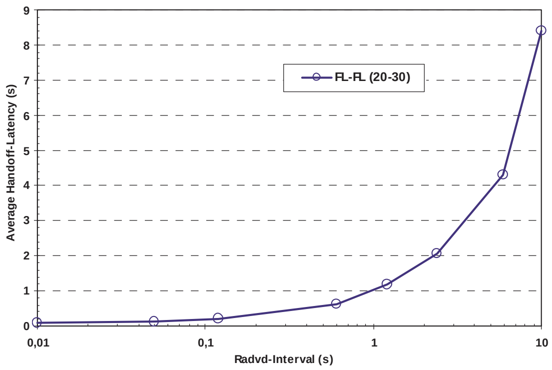

Figure 7: Handoff Latency for varying Router-Adv. Interval.

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The results in Figure 8 and Figure 9 present the average handoff latency with dependence on the link-delay between different networks. Here we directly compared basic Mobile IP to the Fast MIPv6 approach.

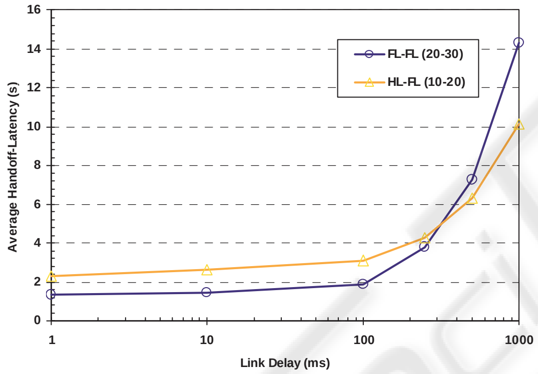

Figure 8: Average Handoff-Delay for Basic Mobile IPv6.

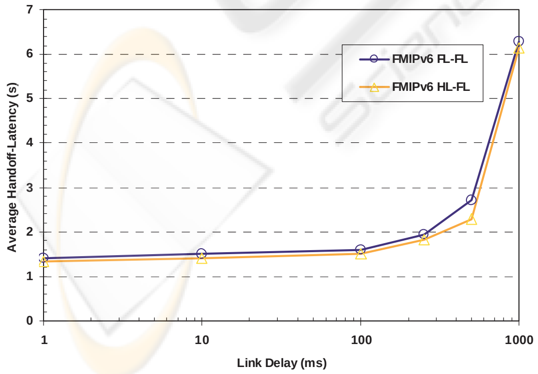

Figure 9: Average Handoff-Delay for Fast Mobile IPv6.

As already assumed from the Fast Mobile IPv6 approach, the packet loss during a handover between different network providers is decreased to a minimum compared to basic Mobile IPv6. Figure 10 depicts the packet loss results for an Iperf- generated UDP-data stream of 160 kbit/s in between the mobile node and its correspondent node. As illustrated in Figure 5 the Correspondent Node is placed near the core network.

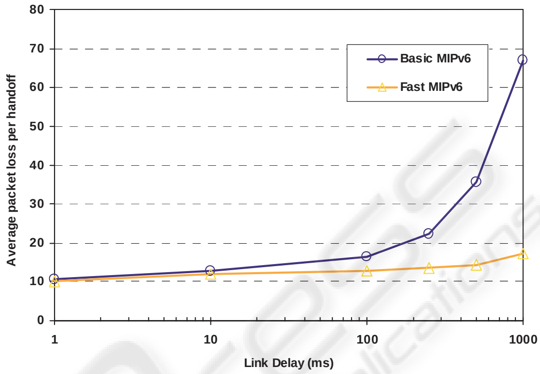

Figure 10: Average Number of Packet Loss during HO.

6 SIMULATIVE COMPARISON

For a deeper understanding as well as for a more general evaluation of Mobile IPv6 in an environment with many users, the use of simulations is indispensable. We performed a simulative comparison of baseline Mobile IPv6 and the Fast Handoff approach in an wireless LAN based scenario, comprising 4 independent operator domains with 10 home users per access router. Even if the focus is on the evaluation of MIPv6 bases protocols, we also include the impact of a shared-link environment based on IEEE 802.11b.

6.1 Simulation Scenario

For the performance study of MIPv6 we decided to evaluate a basic scenario which is simple enough to get results in a reasonable time but also complex enough to get an expressive feeling for real-world provider scenarios. The studied scenario (see Figure 11) is composed of a group of Correspondent Nodes, one for each Mobile Node, connected to one central router (CR) through the IPv6 backbone. Each access router (AR) represents a different IP subnet and acts as a home agent for 10 mobile nodes. All Mobile Nodes are located at their home link when the simulation starts. Either the distance in between the ARs and also the transmitted signal-power are chosen in a way to create overlapping coverage areas for enabling seamless movement in between the various domains (see Figure 12).

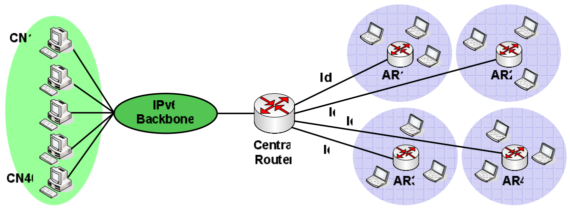

Figure 11: Mobile IPv6 – Simulation Scenario.

The random way-point mobility model is used for all Mobile Nodes, which is best suited for realistic user movement. Connectivity for each Mobile Node is provided by IEEE 802.11 using 2 Mbit/s and DCF and traffic is assumed to be UDP with 40 kbit/s constant bit rate.

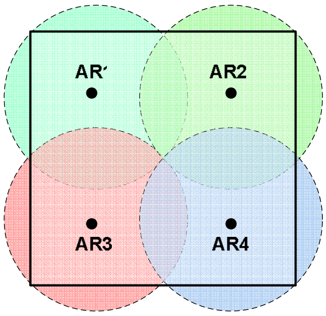

Figure 12: Access Router Range Topology.

For all our experiments we used the ns-2 (Ns2, 1998) simulation tool, whereas the MOBIWAN add-on by Thierry Ernst (Ernst, 2002) is deployed to get basic MIPv6 functionality into the simulator. Further essential MIPv6-specific software code was adopted from a MIPv6 simulation environment by NEC Europe in Germany.

6.2 FMIPv6 Simulation Results

In this section, we present the results of our ns-2 simulative comparison of baseline Mobile IPv6 and the enhanced Fast Handover mechanism.

Figure 13 presents the comparison of the handoff latency obtained during basic Mobile IPv6 handoff with the latency resulting from a Fast Mobile IPv6 handover. The simulation results show that similar to the performance measurements in Section 5 we also achieve some latency-related advantage for scenarios with a huge number of concurrent moving users.

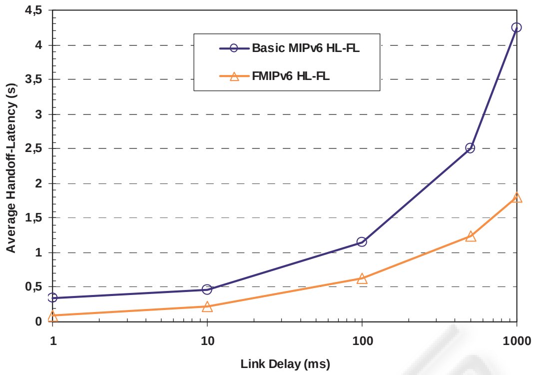

Figure 13: Average Handoff Latency Comparison.

With a reduced latency also the packet loss during the handoff can be reduced consequentially for the Fast Handoff approach. This behavior, similar to our testbed results from Section 5, is demonstrated in Figure 14.

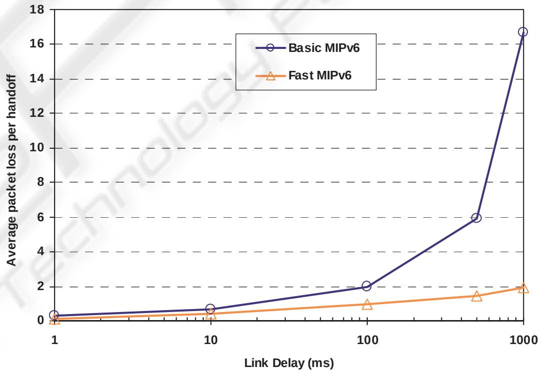

Figure 14: Average Packet-Loss per Handover.

7 CONCLUSIONS AND FUTURE WORK

With this work we presented a first evaluation and simulative results of a Fast Mobile IPv6 handover approach for wireless LAN based networks. Our evaluation showed that a client based fast handover approach can be suitable to improve WLAN handovers for real-time traffic and enables better mobility management support in IEEE 802.11 based wireless LANs. In the near future we will investigate on hierarchical approaches for IPv6 and other smart solutions with improved handoff latency performance and reduced signaling overhead.

ACKNOWLEDGEMENTS

Part of this work has been performed within the project "WISQY - Wireless InterSystem Quality-of-Service" at the Telecommunications Research Center Vienna (ftw) and has been funded in the framework of the Austrian Kplus Competence Center Programme. We would also like to thank Uschi Christalon-te Kock from NETGEAR for the great support within our research and Richard Menedetter for his assistance during the measurements.

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