Phone-to-phone Video Data Spreading for Community Health Alerts

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***Abstract*—In this paper we address the problem of spreading health emergency information in the form of rich media content, particularly video, among a set of population in an efficient manner. Video data are very useful to convey useful information in the wake of a health alert in a community, such as informing people about symptoms amid of outbreak of a certain contiguous disease. Instead of asking people to visit a website to watch instructional materials, our approach pushes videos onto people devices and spread them into a certain population set as deem necessary. We leverage the ever increasing trend of people's having mobile phones capable of communicating with other phones over wireless peer-to-peer (for example, by using WifiDirect) as well as capable of playing videos. In that, we propose a novel dissemination protocol in which awareness video content is segmented into chunks, and the chunks are disseminated opportunistically onto other devices reaching out onto the population eventually. We discuss strategies for a device to choose specific video chunks to transfer to another device as they communicate. The selection strategies were simulated using real time movement trace in a large scale simulated environment using ONE simulator. We also build an Android based mobile app that enables user mobile devices having WifiDirect to take part in video content dissemination.**

***Index Terms*—Delay-tolernat networks, phone-to-phone communications, WiFi-Direct.**

I. Introduction

Due to burgeoning ubiquitous trait of computing devices, mobile phone has become a common phenomenon in every corner of the world. Increasing computational capabilities, context-awareness capabilities, accessibility, and availability has led mobiles phones to be a powerful medium to spread awareness information. The ubiquitous nature of mobile phone and the current trend of replacing old technologies by mobile devices are implications that mobile phone is more stronger medium to spread health intervention that television or radio. A lot of investigations have been reported in literature about feasibility of mobile phone usage to in health-care organization. Mobile games in mobile phone has been proved effective in educating individuals about health issues [1]. The context awareness abilities of modern mobile phone has also paved the way to design and deploy context-aware clinical applications in hospitals and public spheres [2]. Mobile phone has been proved effective in spreading nutrition information, smoking cessation [3], spreading diabetes information [4], surveillance of patients [5] etc. While much of the investigations are directed towards application of mobile phone in health intervention and effectiveness of video content in spreading awareness [6], not much works are found in literature that focuses in the underlying technology that facilitates such dissemination in resource-constrained settings where Internet can often be scare. We concentrate our efforts in analyzing opportunistic networks comprising P2P connections among mobile phones in spreading awareness video and propose a novel protocol for efficient dissemination.

We envision a specific use case around spreading health-related video content. Sometimes health emergencies arise, and people of a community need to be aware of certain health concerns immediately, for example during an outbreak of a certain disease people should be aware of symptoms of that disease and possible first hand protections, cures and other guidelines. A small video snippet would be very helpful in this regard as video carries more information than ordinary textual means. It is not unlikely to find plethora of such video content in popular streaming websites, e.g., YouTube. It can be also case that concerned health departments as well as people voluntarily can produce educational video materials themselves, and let them spread onto the community.

Wide spread video dissemination, however, has several problems. Not all people have Internet connections. Even though they have, they may not opt to download large video content if they are in a budgeted data plan. We attempt to leverage people's smart phones capable of connecting other devices nearby through a short range communication such as Bluetooth and more recent technique WiFi Direct [7]. This allows individuals to exchange their digital contents free of charge (because it does not involve the carrier they are in). This creates an exciting medium of spreading awareness video through people. To this end, we propose a video dissemination technique for spreading video. We assume a couple of members in the community, we refer them to "seed nodes", first download the full video content from a designated location, and then *split* it into several smaller chunks and transfer these pieces opportunistically to other devices when they come close by. It may not be possible to transfer all chunks in a single opportunity, but some of them can be. As chunks are spread all over, devices receive different chunks from different nodes and can eventually accumulate all chunks after a while to construct the full video. We show that starting a small number of seed nodes, video chunks get propagated across the target population within a considerable amount of time.

The paper is organized as follows. In Section II we descrive some seminal background works. In Section II we discuss our proposed protocol and its operational settings. In the next section, we discuss the mobile phone implementation of our protocol. Then we discuss the evaluation of the protocol in simulated environment. Finally, we conclude by proposing future direction of our work.

II. Related Work

Mobile phone has been exploited for not only monitoring, assessing, augmenting health conditions but also spreading health information. Margaret et al. has studied the potentiality of mobile phones in providing cognitive behavioral therapy [8]. Their participatory user study has showed that mobile phone application can increase self-awareness and help to cope with stress. Megan et al. evaluated the effectiveness of short messaging services (SMS) in augmenting sexual health awareness [9]. The increasing integration of mobile phone in healthcare and public health sector has also changed how health professionals interact with their patients. Kevin et al. has examined such phenomenon along with health hazards related with using mobile phones [10]. Wanda et al. [11] has identified five features of mobile phones that makes it an attractive medium of healthcare - (1) the widespread adoption of phones with increasingly powerful technical capabilities, (2) peoples tendency to carry their phones with them everywhere, (3) peoples attachment to their phones, and (4) context awareness features enabled through sensing, (4) phone-based personal information. Jami et al. argued incorporation of SMS in smoking cession [3]. While mobile phones can be a powerful tool for health intervention, it can also play a strong role during natural or artificial calamities. Herse et al. has investigated the role of mobile phone in disaster management [12]. Jonas et al. studied the patterns of interaction among actors to show how the dyadic exchange of mobile phone numbers between the actors plays an important role in emergency situation [13].

Video-based health education has been proven to be effective. Nayla et al. has evaluated the performance of an online video-based education system in this regards [6]. In case of medical emergency like spreading of an epidemic disease, environmental catastrophe, spreading health information plays a significant role in upholding public health and often demands rapid dissemination. However, incorporation of internet bandwidth cannot always facilitates efficient and fast convergence due to lack of access to ample bandwidth. Marshini et al. has investigated resource-constrained environment where bandwidth capping is a widely prevailing phenomenon [14]. In this paper, we focus to incorporate P2P communication in a network of mobile devices rather than internet bandwidth with an eye to efficient and less resource-consuming dissemination technique. We use WiFi Direct to spread health related information. Wi-Fi Direct is capable of connecting to other devices without a wireless access point []. By simple discovery and directly connecting to other devices, Wi-Fi Direct makes easy to share, print and display contents to other devices. However, incorporating Wi-Fi Direct in video dissemination process demands robust analysis of delay tolerance inherent in mobile network.

As the nodes are mobile and there may not exist stable connection between nodes, traditional routing protocol might not come handy in Delay Tolerant Network [15]. A large number of literature are found addressing the problem of routing in an opportunistic network. Protocols in this regard can be divided into two families Flooding family and Forwarding family. Flooding strategy uses the replication and forwarding strategy uses knowledge [16]. When path information is known the message is then forwarded from node to node in this network. The routing protocols in this family requires some knowledge about the network [17]. Some routing protocols presume no prior knowledge regarding the topology of the network such as Epidemic [18], [19], Spray and Wait [20]. These algorithms disseminate the messages in a nondeterministic fashion. Some algorithms such as Prophet [19], SCAR[21], MaxProp [22], [23] allow only one node to carry a specific message always. The messages are then forwarded to nodes which have higher chance to meet the destination. Some alternate approaches [24] use erasure coding technique for efficient routing of messages. While disseminating data among a set of nodes in an opportunistic network two important issues arises. Chunk size and chunk selection. Pitkanen et al. studied the impact of data fragmentation in one-to-one opportunistic network [25]. Nadan et al. proposed a cooperative strategy for content downloading in vehicular networks [26] with chunk selection process based on a proximity-driven strategy called rarest-closest. Some other solutions only considers one-hop communications [27], [28] with uniformly-distributed random piece selection. Our work focuses mainly on selecting some random sources which will work as the initial seed for disseminating the content over the network. We will describe three techniques for selecting pieces to disseminate the file pieces into the connected node: Random Sending, Least Disseminated Content First Round Robin/Sequential Technique. In addition we design and implemented a mobile phone application using our proposed chunk selection schemes and simulate the protocol in ONE simulator.

III. Video Chunks Dissemination

In this section, we describe our health awareness video dissemination technique. Video contents are passed from one device to another opportunistically when the devices come close so that they can establish a communication between them over their radio interfaces (either using Wifi or Bluetooth). These opportunities happen sporadically and mostly remain for a short time until the devices in question get departed as they move on, and the connection between them tears down. We refer to these data communication opportunities as *contacts*, and the duration to which the contact remains is called *contact duration*. In the following, we use the terms, nodes and devices interchangeably.

A. Fragment of Video Contents

Since video data is large in size (can be upto several megabytes) and contact durations are small, it may not be possible to transfer full video content over a single such contact. For this reason, we fragment each video file into a set of small *chunks* of constant sizes so that at least a single chunk can be transferred with most contacts. If contact duration allows, however, multiple such chunks can be transferred from one device to another back to back, only causing a possible disruption for the last chunk that may be in transit when the connection breaks. In that, the last chunk is failed to get transferred. Note that, when we say a sender transfers a chunk to another node, the sender does not necessarily gets rid of the chunk; instead both the sender and the receiver contain the chunk in their respective buffer.

We assume that at the very beginning of the dissemination process, only a very few nodes in the network possess the video contents in *full*. These nodes are referred to as *seed* nodes. The seed nodes then spread these chunk into the network and eventually let other nodes to have then. The question how these video contents arrive at the seed nodes in the first place remains open. We assume there could be some out-of-band operation by which they are obtained by the seed nodes.

A seed node, after receiving a video file, splits the file into a set of chunks of equal sizes (k bytes). It also assigns a unique ID to the video content so that other nodes can identify which video files they have chunks for. For simplicity, chunks are assigned ordinal numbers, such of for a video file with ID `abcdef`, chunks are named as `abcdef-0`, `abcdef-1` and so on. This ID's are initially populated by the seed nodes and written in chunk headers, and later copied to other nodes as chunks get exchanged. After the full content is fragmented into chunks, the seeder initiates the spreading process by transferring these chunks onto other nodes when it contacts with other nodes. The receiving nodes are then in turn meet another set of nodes and push these chunks onward. Thus, video chunk get spread into the network as contacts happen among nodes and at some point in time all nodes in the network eventually accumulate the full content. Although it is possible there can be multiple video contents spreading in the network from one or more seen nodes, for the ease of discussion, in the following, we assume a single video file is getting disseminated from a single seed node.

B. Disseminating Video Chunks

As part of the dissemination process, when a contact happens (i.e., a pair of nodes get connected) in the network, the two nodes in the contact exchange their chunks (preferably the chunks that the other node does not have). In order to identify which chunks a particular node currently possesses, each node maintains an encoded *bit vector* (for each video file in dissemination) indicating which chunks it has now. For example, a bit vector, `01001`, indicates that the node has chunk 1 and chunk 4, but not other chunks (i.e., 0, 2, and 3). The length of the bit vector is equal to the number of total chunks of the particular video file.

When two nodes connect, a simple bitwise operation over the respective bit vectors can indicate which set of chunks the pair need to exchange. In particular, one node finds the set of chunks that it has but the other does not have. This set is represented by yet another bit vector. Let node I and node J be in contact who have some subset of the chunks of a given video file. We also denote their respective bit vectors using the same symbols, I and J. Let $I = 11001$ and $J = 10010$. Hence, node I finds its chunks to be transferred to node J as a bit vector, 01001, that is, chunk 2 and chunk 5 need to be passed to node J (which node J does not currently have). Similarly, node J computes 00010 for node I. More formally, node I computes $I \wedge \overline{J}$; the logical AND between its own bit vector and the inverse of J's. Similarly, node J computes $J \wedge \overline{I}$.

Once nodes in contact identify their transfer chunks, they schedule transferring these chunks to the other node. Now an important question arises as is in *which order* nodes need to send these chunks across the connection considering the fact that the connection sustains only a small and uncertain amount of time. Apparently, considering one chunk over another may have effect on accumulation of chunk among nodes as the dissemination process progresses. We propose three chunk dissemination schemes, which are namely, i) round robin, ii) random, and iii) least disseminated content first. In the following, we describe our three schemes.

1) Round Robin Scheme: In this scheme, nodes select chunks sequentially from the their transfer list one after another.

Algorithm 1 Generic Chunk Exchange Protocol at Node I

function ONCONNECTEDWITH(Node J)
  Compute bit vector $I \wedge \overline{J}$
  Find list of chunks, L, for $I \wedge \overline{J}$
  while $L \neq \emptyset$ **do**
    `OrderChunks(L)`
    $chunk$ = get first item from L
    `Transfer` $chunk$ to Node J
    Update state at Node I as $chunk$ is transferred
    Remove first item from L
  end while
end function

2) Random Scheme: The random scheme selects a random chunk for dissemination from the list of deliverables with respect to node I to node J. Then it continues the dissemination until the dissemination is complete or the connection gets disrupted between nodes I and J.

3) Least Disseminated Content First: The last suggested scheme for consideration is least disseminated content first scheme. We will refer to this term as LDCF from now on. Here the intuition is if we disseminate the same packets over the network and there is not enough connection made over time, then the network might become saturated with the same packets. So we suggest LDCF scheme which disseminated the packet which is least disseminated with respect to a node.

We analyzed the convergence of the chunk dissemination process by applying mathematical models from Epidomology, which models contamination of disease in a certain population. Our chunk dissemination shares a similar analogy. Due to space limitation, we do not show those analytic results in this paper.

IV. Mobile Phone Implemention

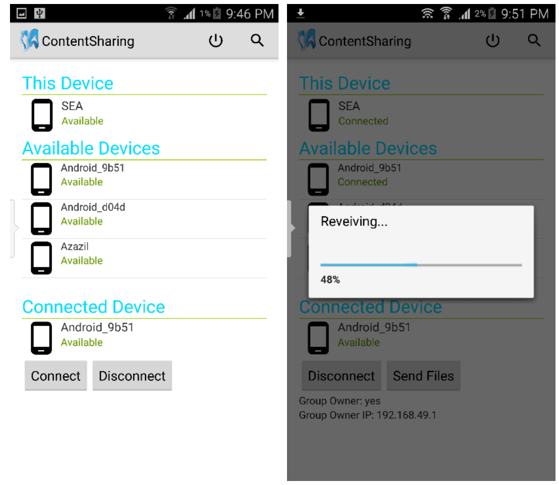
To transmit rich media contents in opportunistic network, we have to slice data into pieces and transfer them individually when two nodes meet. The challenge of this strategy is to design the scheme for deciding which piece to transmit at a standard size of the selected piece. We argue three piece selection strategies - *Random*, *Round Robin*, and *LDCF*. To evaluate the performance of Round Robin in real opportunistic networks we have designed an application,*ContentSharing*. We have designed the application, *ContentSharing* in Android platform. We used wi-Fi Direct as P2P communication medium. Wi-Fi Direct is the fastest short range communication medium which is capable of connecting among devices without a wireless access point and can transfer data at a speed 250 Mbps maximum. Wi-Fi Direct establishes connection using Wi-Fi Protected Setup and WPA2 security which prevent unauthorized connection to protect our communication.

ContentSharing uses Android's Wi-Fi P2P framework to transfer data. Android's Wi-Fi P2P framework complies with the Wi-Fi Alliance's Wi-Fi Direct certification program allows Android 4.0 (API level 14) or later devices with the appropriate hardware to connect directly to each other. After enabling the Wi-Fi Direct, application searches for peers to connect. A list of available devices will appear at the end of the search. After establishing the connection between two devices, a group owner will be selected by the API. Group owner will act as server and the other devices will act as client. At first server dont have the client IP. To establish a two way communication client IP must have to be known. So client sends an echo message to server. After receiving echo, server saves the IP of the client. Now server and client both can send files to other. Round Robin scheme is implemented to select the pieces. Before start sending pieces device send a request to send information about pieces to the connect device to decide which pieces it need to be send. The connected device response with the information about its files.

Device calculates the piece selection process and send the selected piece to the connected device. Connected device sends an acknowledgment to the device with the updated information about its received files. The sending device again calculates and send next piece to the receiving device. This processes continues until all pieces are sent. After receiving all pieces, its receiving time is saved in the information file for further analysis. In Figure 1, we have showed the sending and receiving UIs of our application.

V. Experimental Results

We discussed in detail our proposed dissemination schemes in the previous chapter. We mainly used simulation environment to assess the efficiency of the algorithms. The tool that helped to gain different performance metric was ONE simulator environment which enables users to emulate DTN hosts based on default and custom routing protocols needed. But real world results are somewhat different than simulation environment as there is randomness in the behavior of the individual. We developed an application which was discussed in the previous chapter.



(a) Application Screenshot I (b) Application Screenshot II

Fig. 1. Mobile applications screen-shots.

A. Opportunistic Network Environment(ONE) Simulator

We used Opportunistic Network Environment [?] simulator for our simulation. A good number of simulation runs were made to reach results for different performance metrics. We will mention each performance metric and their simulation environment in great detail to reach our experiment results. ONE simulator is capable of generating custom report based on user demand. We used some of the in-built report generating utility to asses our proposed routing schemes as well as the in-built epidemic routing protocol.

B. Simulation setup

In the simulation, we consider a scenario where we spread a health emergency video among 150 people moving around a city. The factors that we vary in the simulation are movement models for the nodes, the movement speed of the nodes, the chunk sizes, network bandwidth, and the routing protocols. We used a small urban city map that is accompanied with the simulator. All simulation runs were done for 86000 seconds (1 day). We make repeated random runs to get the mean value of our desired performance metric. The simulation environment consisted of people interacting with each other in a regular city manner. All the nodes were given the transmission radius of 65 which is equivalent to the transmission radius of Wi-Fi Direct.

C. Performance Metrics

The metric for evaluating the efficiency of Round Robin, Random, LDCF, Epidemic scheme was to plot the number of

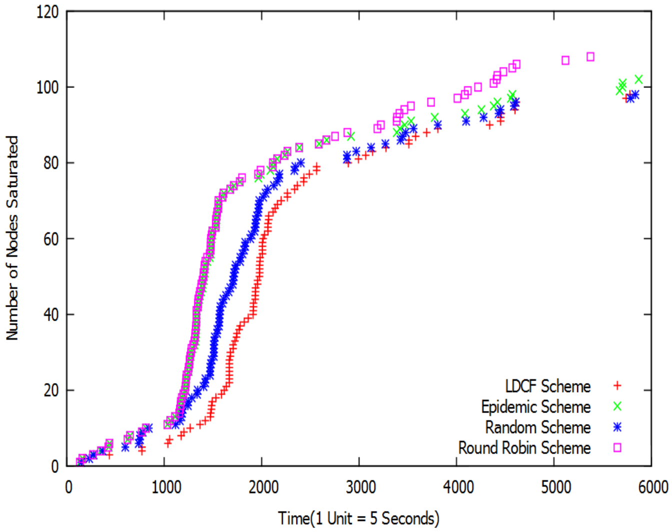


Fig. 2. Time(Seconds) vs Convergence plot for Random, Round Robin, LDCF, Epidemic Dissemination Scheme

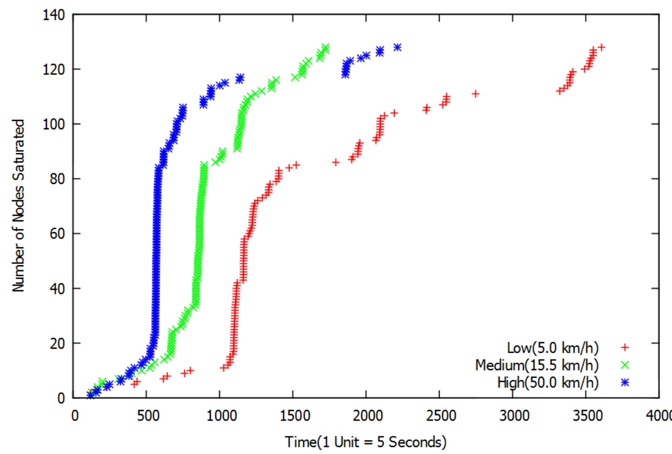
nodes saturated against time. Saturation means refers to a node receiving all chunks to construct the whole video. We also observe the total convergence time against different channel bandwidth. We varied bandwidth with a step increment until a point where the total convergence time did not drop anymore. A combination of series curves are plotted to show the effect of packet size on the total convergence time. The total data size 10MB, and we use 1MB, 2MB, 4MB and 10MB to plot the series curves for Random, Round Robin, LDCF schemes. Our next performance evaluation is based on the movement speed of the mobile devices users. We use three movement speeds: normal walking speed(5km/h), medium speed (15.5 km/h), and high speed (50.0km/h).

D. Evaluation

The first plot shows the comparison of four dissemination algorithms: Random, Round Robin, LDCF and Epidemic. In Figure 2, as illustrated, time in seconds appear in x-axis, and y-axis shows the total number of nodes saturated. The mean value was used for plotting the curve for hundred runs. Standard deviations are 3.9 (Random), 5.3 (Round Robin), 4.86 (LDCF) and 6.44 (Epidemic).

Movement speed plays a major role in the dissemination of the chunks in the network. It is intuitively realizable that if the movement speed is higher, the convergence will be faster than a comparatively static network. These results are depicted in Figure 3. As the mobility of nodes increases, the connection stability decreases. In this simulation, transmission radius is set to 65, packet size set to 1MB, channel bandwidth set to 3MBps, only the group speed are varied. In the x-axis, we plot time and in the y-axis, we show the number of saturated nodes with varying speed for the same algorithm.

The next thing that we show is how channel bandwidth impacts convergence time. We start varying transmission capacity from 1MB to 5MB with 1MB increments. Th x-axis of



(a) Impact of movement speed on the convergence of Round Robin Dissemination Scheme

Fig. 3. Impact of movement speed on the convergence of Round Robin

Scheme name	LOW Speed	Medium Speed	High Speed
Random	5.45	6.77	7.23
Round Robin	4.78	6.23	6.99
LDCF	6.38	6.15	7.79

TABLE I
STANDARD DEVIATION FOR RANDOM, ROUND ROBIN AND LDCF FOR DIFFERENT SPEEDS

the bar chart of Figure 4 shows the transmission rate of each node, and the y-axis shows the time needed for the entire network to become saturated. Video data was split into 10 chunks in this simulation scenario. Each chunk was of 2MB. The bandwidth is varied with 1MB increment. We observe that the convergence time gradually decreases as transmission rate increases while other parameters remain constant.

E. Interpretation of Results

It can be seen from Figure 2 that the Round Robin technique yields better performance compared to the other three schemes.

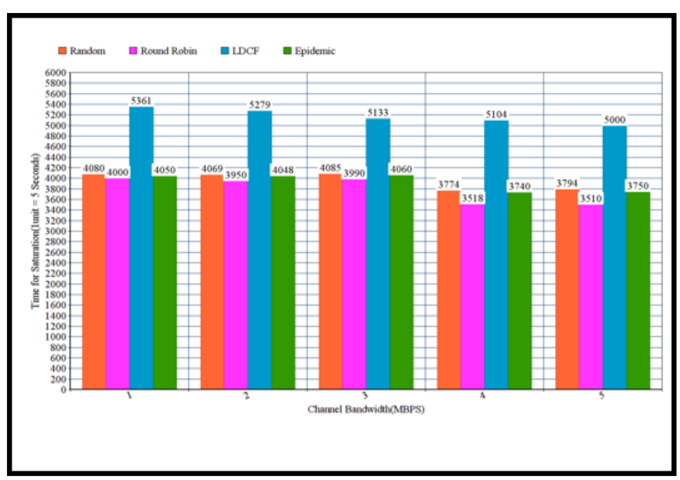


Fig. 4. Impact on convergence of the transmission capacity

Initially, Epidemic scheme performs almost as same as Round Robin Scheme, but as time passes, Round Robin precedes epidemic, random and LDCF.

As our network is dynamic, movement is one of the large factors that affects the convergence time. The more dynamic the nodes are in the network the higher the chances of convergence in the network. But higher mobility means lower contact time in the of each nodes. In Figure 3 we can see that lower speed (the speed of walking) results in the lowest convergence curve. As speed increased (indicating the speed of running), the convergence curve moved upwards indicating better convergence rate with respect to time.

As the transmission capacity increases, the total convergence time drops steadily. The packet size was fixed to 2MB for all the simulations. It is observable from Figure 4 that round robin performs better than all the algorithms that were proposed for dissemination. As the bandwidth was increased, the total convergence time dropped steadily for all the algorithms.

VI. Conclusion

This paper showed the promise of leveraging people mobile phones for spreading health alerts video data in a community. We propose several techniques of video chunk spreading and show their performance in a simulation based study. We also develop a mobile app that users can user to take in dissemination. While the paper contains a proof-of-concept, much efforts can be made in this direction. One immediate try can be to deploy the app at large and observe the challenges and limitations it encounter. Capturing and spreading video, sometimes, may have privacy invasion and severe misuse consequences. These are also other concerns that we need to take care of in future.

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