Chapter 27
Exploring IoT Applications for Disaster Management: Identifying Key Factors and Proposing Future Directions

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Abstract In the last few decades, disasters made a huge loss to human beings, natural resources, and other assets. As we are living in an era of technology, there can be no other way better than using ICT (information and communication technology) for disaster management, as communication is the most challenging part of it. The Internet of Things (IoT), a rapidly emerging framework, can be utilized in the best possible ways for the disaster preparedness phase to recovery phase. This paper presents the survey of the work done for disaster management using technology. A detailed analysis has performed to categorize different approaches of disaster management based on supporting phase and technologies used. The best used technology is highlighted. Moreover, forecasting about the growth of its usage and the enhancement in disaster management is also done in this paper. The paper also presents new direction of research in this most attention-grabbing topic.

27.1 Introduction

27.1.1 Internet of Things

As technology is enhancing, a society is formulating, where everyone will be connected to everything [1]. It allows real-world devices and applications to develop independent connection and exchange of data between each other. The Internet has grown tremendously in recent years as it connects billions of things worldwide. IoT technology is being increasingly applied to diverse application areas including healthcare monitoring, disaster management, and vehicular management [2].

Making the IoT paradigm more tangible requires integration and convergence of different knowledge and research domains, covering aspects from identification and

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communication to resource discovery and service integration [3]. In IoT, there are many objects, sensors, communication links, or framework and processing units that can be beneficial for decision-making and action entreating systems with the help of different technologies [4]. The basic architecture of IoT is constructed on four layers: perception, network, service, and interface layer [5].

Major elements in an IoT concept are sensors, RFID, WSN, WiMAX, etc. In a WSN environment, the components which are important to consider for WSN-monitored environment are WSN hardware, Communication Stack, WSN middleware, and Secure Data Aggregation [6, 7]. Thus, in an area of interest, it is significant to obtain the location information of sensor nodes within the margin of error [8]. Here, we highlight the Sensor Web and categorize into these types: space, underground, underwater, and creature sensors [9].

– Space sensors indicate tropical sensors such as satellites: using imagery to a hot spot to monitor the spread of forest fires, using multi-sensor data sets of remote sensing and models.
– Underground sensors are those which are usually concealed in the soil, a layer of ice, and other geographical strata or assimilated in underground pipes, to observe the mud slide disaster and to measure pore water pressure tensiometers.
– Underwater sensors state the sensors throw down into rivers and lakes or integrated sensors with pipes under the water such as undersea sensors.
– Creature sensors refer to the sensors embedded in the integral part of animals or human bodies to observe their behavior, health, locations, and other factors.

Another well-known technology for IoT is the RFID technology. It is a basic and broadly used technology in this context and considered as criterion for the IOT. RFID tags can automatically identify and track any object [10, 11].

An RFID system has three parts [12]:

– RFID tags, of two kinds either active or passive, refer to transponders attached to objects to identify and count.
– A reader or transceiver is a combination of radio-frequency interface (RFI) module and a controller.
– A data processing/application system, depending on the application, may be any application/database or any other system.

27.1.2 Disaster Management

It is an incessant process in which efforts are made to manage risks and to avoid the effects of disasters with the help of different authorities. Operative disaster management is based on full incorporation of emergency plans at all stages of participation by different authorities [13–17]. Any disaster can be managed at different levels called phases of disaster management which are shown below in Fig. 27.1. Data collected from the sensor nodes transmits to a centralized control center

Fig. 27.1 Disaster management phases

and then to emergency operations center and rescue authorities through various communication media, for example, RFID, wireless sensor networks, GIS/GPS, mobile networks, and satellites. The disaster detection and warning dissemination process in the best possible way are shown below in Fig. 27.2.

As discussed earlier, according to the stage at the time of the disaster, it could be divided into two parts: pre-disaster and post-disaster. It contains detection, monitoring, and forecasting in pre-disaster phase, or we can say it's the time when a disaster just occurred, while search, control, and rescue operations during disaster and recovery as well are the parts of post-disaster. In this paper the focus is on both the pre- and post-disaster management. Disasters cannot be eliminated, so it is very important to find solutions to damage associated with them [18–22].

The purpose of conducting this research is to review the maximum number of approaches used for disaster management in last years. Through it we categorized that which specific technology is used and which phase of disaster management is supported through any specific approach. Based on this study, we analyze and highlight the most commonly and effectively used technology and its future growth. Also, we predicted that in the coming years, improvement in people's awareness about disasters and its management will be enhanced and presented in some graphical values.

The rest of the paper is structured as follows. Section 27.2 presents the literature review of the work done for disaster management through technology. In Sect. 27.3, an overview of the technology usage in the context of disaster management and their evaluation is reported. The paper continues with an analysis and presented

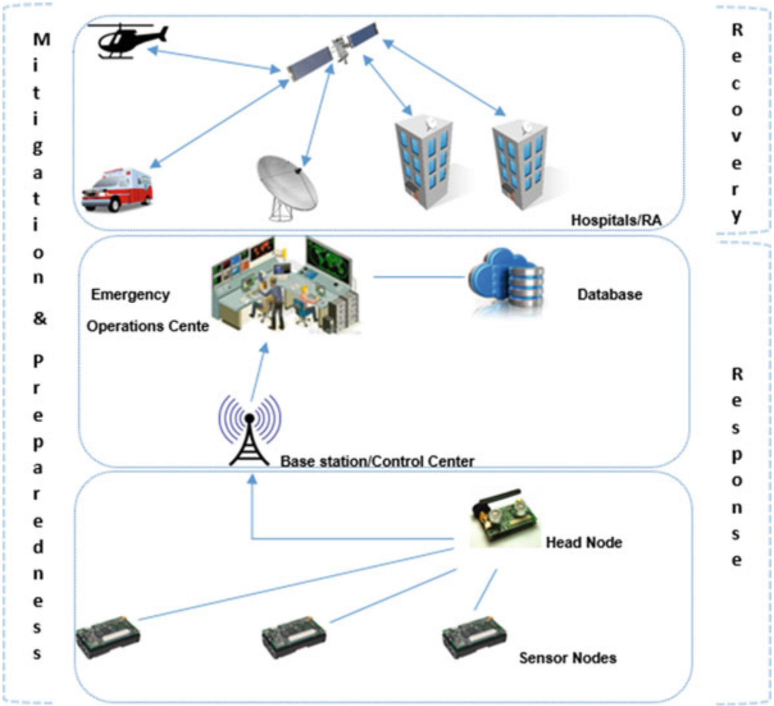

Fig. 27.2 Disaster management process

current and expected trends related to disaster management. Section 27.4 discusses the analysis, while Sect. 27.5 presents the authors' conclusions.

27.2 Disaster Management Approaches

Several disaster management approaches have been proposed in recent years to minimize the loss or damage and enhance the process. These include collaborative computer-based system or embedded system which is integrated with different ICTs. Different researchers have proposed different methodologies.

27.2.1 Pre-disaster Management

It refers to managing disaster in mitigation and pre-preparation phase. It includes mitigation measures to reduce exposure to the effects of disasters such as injuries and loss of life and property, while preparation is focused on expecting how much a disaster can affect the community and how to react and recover from that situation. It refers to the steps taken to prepare to minimize the impact of disasters, i.e., to predict and prevent.

By analyzing flood prediction techniques built on GIS by means of ad hoc wireless sensor network [23–25], a model for flood prediction is proposed which is considered to be helpful for calculating the influence of flood damage with the use of GIS simulation tool [26]. When it comes to prime to detect prime location of ambulance and or other rescue authorities, Google Maps integrated with GIS simulation tool can help [27, 28]; moreover flood risk analysis can be performed through its use [29]. Another important factor is that for flood management GIS can utilize unit hydrographs effectively [30, 31].

An IIS (integrated information system) [32] was introduced named as '*architype*' early warning system for snowmelt floods. It works by incorporating with IoT and Geo-informatics for management of resources.

In [33] remote sensing and geographic information systems were used for the estimation of the flash flow-flood area. GIS can deliver risk assessment and public administration of natural exposures.

A framework of early warning system [34] was prototyped which integrates three components: rainfall-induced landslide prediction model (SLIDE), susceptibility model, and satellite-based forecasting model. Permutation of EEWS (earthquake early warning system) and RSMS (real-time strong motion monitoring system) was applied for response phase during an emergency in [35]. The stratagem is PDCA cycle: plan, do, check, and action.

Decentralized message broadcasting approach for sensor cooperation [36] is introduced to address the issues of message encircling in the system and event's identity confusion. Node level and network level virtualization can be practical to evade redundant placement of weather sensors [37, 38] for weather data alerts, which supports different kinds of applications for propagation of weather sensors. Earthquake alert system for Pakistan [39] was proposed which used different open-source technologies, like it takes real-time earthquake data from US Geological Survey (USGS) public API.

In [40] multi-hazard early warning and response system was considered, which focuses on reducing seismic alert time by exploring the use of vigorous seismic sensors in WSN such as Wi-Fi, WiMAX, and Zigbee which are used for different categories of networks. For detecting the earthquake, real-time wave signals are used in EEW (earthquake early warning) system [41, 42]. People are alerted on the basis of magnitude, velocity, and displacement detected. SEWAS (seismic early warning alert system) [43] warns people about imminent strong shake, so that peoples could take appropriate actions quickly, maintaining the integrity of the specifications.

27.2.2 Post-disaster Management

It includes strategies to support rehabilitation after a disaster and recovery cover which are oriented toward the reestablishment of human-centered services and infrastructure, as well as the restoration of physical and ecological veracity of the affected ecosystem.

In [44], a mini case study of occupational hazard is considered after which solutions assumed are the use of plasters by each operational unit team which can collect data about environment and sensor APIs on victim's mobile phones and finally grids, cloud, and crowd source computing for data processing and analysis through which disaster managers outside the building can get all information.

Usually Web services provide exiled, determined facilities, while grids offer state-full, transitory illustrations of objects [45]. IoT and DfPL system can account the RSSI dimensions that can perceive the presence of humans in an environment (location affected by disaster) [46]. There are many existent ways for implementing WSN in IoT scenario [47], such as smoothing algorithm "SavitzkyGolay" and classifiers like Naive Bayes, Tree Bagger, etc.

In [48], a research is conducted to support two hypotheses which are: (1) IoT technology convulsions acknowledged information requests and (2) IoT has added significance to disaster response processes. A project named SIGMA was presented [49] exploiting cloud technologies to attain, incorporate, and compute records from multiple sensor networks.

An emergency management system based on IoT architecture was proposed in China, which can monitor any disastrous situation using sensors and intelligent video [50]. In response to "Typhoon Morakot" in Taiwan, discussion research [51] suggests that a system of emergency response via the Internet can allow people to report any emergency to the government by using mobile wireless devices or computers to assist in search and rescue operations. A system [18] for evaluating disaster synthetically was designed based on seismic networks of things, which can collect data through IoT in real time and then estimate the loss and forecast by GIS. IoT may exercise the directional control function and accurate forecasting and discard sudden emergencies effectively through different technologies [52].

Development of an instinctive user interface [53, 54] to dynamically manage changes in workflow essentials of an emergency using WIFA approach incorporates the concept of IoT to enable the performance of decision-making. For consistent access to distributed database during any emergency, an emergency Role-based Authentication/Authorization Protocol (eRAAP) integrated with an RFID service (ROY) can be used [55]. RFID embedded portable devices and tags can be used to publish the collection, storage, and with fewer errors efficient way to share building assessment information to improve efficiency and effectiveness in the process of emergency management [56].

Adoption of RFID in emergency management is mainly triggered by organizations' goals to reduce response time [57]. With IoT concept real-time information and situational awareness via RFID, WSN can be gathered, and this inclusive data can be presented to the emergency personnel [58, 59]. RFID electronic tags have been installed on cylinders of hazardous chemicals and gas bottles for dangerous goods detection as well [60]. An emergency management system based on WSID (wireless sensor identification) is designed and implemented in order to solve the inconvenience of aid persons [61]. In a disaster scenario, response time is a crucial factor, so the time required to respond should be more concerning for disaster managers [62], because quick response to any disastrous event enhances the recovery, minimizes property damage, and helps in saving a life [63]. In disaster management scenario, dynamically linked objects were used as smart resources in IoT-enabled smart environment, and its modeling through social networking analysis was proposed [64].

A WoO-based emergency fire management system integrated with ViO (virtual objects) was proposed in [65, 66] which are derivate from physical objects and interconnected in semantic ontology model. WoO kept the option of cooperation between things, humans, amenities, resources, and different sorts of concrete things such as virtual objects [67].

IoT-oriented service architecture for logistics management which is concerned to emergency response was proposed in [68, 69] employed RFID smart sensor networks as objects enabled network architecture. MyDisasterDroid [70], an android application, was developed which facilitates the rescue operations and work in response phase during a disaster. Studies revealed that cellular technology could be utilized for dissemination of pre- and post-disaster warnings effectively [71–75].

In [76] a framework was proposed for data delivery in large-scale networks for disaster management, where numerous wireless sensors are distributed over city traffic infrastructures. Smart wearable devices offer much potential to assist citizens in disasters situations [77]. A new approach proposed in [78] incorporates a mode of disaster on all mobile phones. In [79] two types of IoT-based recovery resource management processes were designed. The first is a resource information management process, and the second is a real-time management and monitoring process for resources that are implemented following disasters.

Taxonomy of the related work done in disaster management through technologies is shown below in Fig. 27.3.

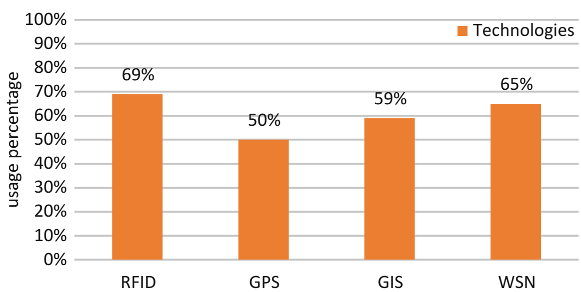

Fig. 27.3 Contribution of technologies in disaster management

27.3 Performance Evaluation

We evaluate the performance of different parameters or technologies used for disaster management in the past or used currently in this section. It provides an inclusive comparison of different characteristics. The analysis is performed using the basic parameters such as parameters for “data retrieval,” “technologies,” “supporting phase,” and the “contributors” to that specific approach or system. Table 27.1 provides the detailed overview of the approaches used for disaster management. A comparative analysis is shown in this table by considering basic parameters which are research focus, practical implementation, data retrieval parameters, technologies used, and supporting phase (of disaster management) regarding different approaches.

27.4 Discussion

We are living in the era next to technology called the Internet of Things, or Web-of-Objects, where each and everything, from ground to high-rise building, can be integrated with technology. This concept is helping us in all fields, but in this paper, we considered it regarding disaster management. As it has multiple phases which are mitigation, preparedness, response, and recovery, we observed that technology is adding benefit to any of these phases, resulting in a contribution in the context of disaster management. For comparison and evaluation, we considered the approaches/systems, their data retrieval parameters, and technologies used in Table 27.1. It shows that a lot of work has been done in this context and the modern technologies like WSN, RFID, GPS, GIS, etc. are no doubt very helpful for reducing the effects of disasters. The analysis show that majorly using technology which is adding real contribution for managing any disastrous situation is RFID with 69% support as shown in Fig. 27.3. Secondly its WSN with a percentage of 65 and its supporting the disaster management at different phases. Then 59% and 50% for GIS and GPS respectively. On the basis of this study, we predicted that at which possible level people awareness regarding emergency situations, disaster management, and use of IoT can be increased in the upcoming years as shown in Fig. 27.4. It is predicted that “people awareness” which is currently 44% could be increased up to 65% in the coming years. “The use of IoT for disaster management” would increase by 19% from now to then, as it is 55% in 2016 and can boost up to 74% in 2020. Most importantly, the overall disaster management which refers to the reduced loss in lives and resources is predicted to increase up to 59% in the upcoming years. In Fig. 27.5, the expected growth of RFID is predicted, which shows that increment in its usage for disaster management during upcoming years is high. Disasters cannot be eliminated and different disaster management systems have been proposed, however, there is a need for more enhanced systems. Figure 27.6 shows the taxonomy of the disaster management systems found in literature.

Table 27.1 Approaches for disaster management

System/approach	Research focus	Parameters	Practical implementation	Tools and technologies	Contributors	Supporting phase
Rapid assessment of flood disaster loss	Disastrous flood area, effected population, and land use are intended by using GIS spatial analysis	Remote-sensed and land use data, basic geographic information data	Yes	GIS, spectrum photometric, remote sensing	Researchers	Mitigation and relief
GIS-based analysis of flood disaster risk	Appearances of flood disasters and the exposed population are analyzed by using ArcGIS	Gridded data from GPW, hot spots, and CAD	Yes	ArcGIS tool	Researchers, government, world population GPW	Mitigation
Flood prediction and disaster risk analysis using GIS-based WSN	Use of ArcGIS simulation tool for flood forecasting in different regions	Air, pressure, wind, snowmelt, and rainfall measurements	Yes	GIS simulation tool, WSN, GPS, remote sensing	Researchers	Mitigation and prediction
Flood risk assessment using remote sensing and GIS approach	Usage of GIS and RS technologies for flood hazard modeling	Land use data	No	GIS, remote sensing	Researchers	Mitigation
Land use effects on flood risk by using integration of GIS and RS	Analysis of flood risk analysis using remote sensing and GIS	Hydraulic modeling, stream basins	Yes	ArcGIS, HEC-RAS, remote sensing	Researchers	Mitigation
Integrated information system for snowmelt flood early warning	A prototype IIS for snowmelt flood early warning system	Meteorological, hydrological, and geographical data	Yes	GIS, GPS, cloud service, remote sensing	Researchers, public	Mitigation and preparedness

(continued)

Table 27.1 (continued)

System/approach	Research focus	Parameters	Practical implementation	Tools and technologies	Contributors	Supporting phase
Flash flood risk estimation using GIS-based morphometry	Satellite data and GIS-based morphometry for flash flood risk mapping	Drainage density and frequency	No	GIS, satellites	Researchers	Mitigation
Earthquake early warning system and real-time strong motion monitoring system in emergency response	Use of EEWS to disseminate advance alerts of ground motions and RSMS for emergency response	EEWS, RSMS	Yes	Sensors, EEWS, RSMS	Researchers	Mitigation, preparedness, and response
Integrating cloud-WSN to analyze weather data and alert users	Cloud-WSN integration to alert users during weather disasters	Sensed data	No	WSN, cloud	Researchers	Mitigation, preparedness, and response
CIVIONICS Earthquake Early Warning System	The CIVEEWS network architecture for fixing up the minimum warning time	Sensed data	Yes	Wi-Fi, WiMAX, and Zigbee	Researchers	Mitigation, preparedness, and response
Seismic early warning alert system	Seismology with the help of GPS to quickly locate an earthquake	Sensed data	No	GPS	Researchers	Mitigation, preparedness, and response
A data collective computational intelligence case proposal for managing disaster	Use of plasters to collect data about environment and monitor individual's health condition, buildings with installed sensors	Sensed data	No	Sensors, Google Maps	Researchers	Response, recovery

IoTs and DfPL in a disaster management scenario	Novel disaster management system that takes advantage of WSN and DfPL concept	Classified data, time stamps	No	Sensors, WSN, DfPL	Researchers	Preparedness, response, recovery
Application of IoT in emergency management system	Hands-free data collection, high-building firefighting, hazard monitoring, and medical and health services using technologies	Mapped, sensed, or captured data	Yes	Sensors, GPS, GPRS, RFID, WSN	Researchers, government	Response, recovery
Web 2.0 and Internet social networking as a tool for disaster management	Internet-based emergency response system based on the use of mobile devices or wireless computers	Environmental data	No	Web 2.0, Internet social networking	Researchers	Response, recovery
Quasi real-time evaluation system for seismic disaster based on IoT	Disaster real-time evaluation system to collect real-time data through IoT	Earthquake magnitude, focus, monitoring network data	Yes	Sensors, GIS	Researchers	Mitigation, recovery
Urban public safety emergency based on technologies for the IoT	Accurate prediction of emergencies through various technologies	Sensed data	Yes	RFID, Bluetooth, Wi-Fi, WSN, LAN	Researchers	Mitigation, preparedness, response

(continued)

Table 27.1 (continued)

System/approach	Research focus	Parameters	Practical implementation	Tools and technologies	Contributors	Supporting phase
RFID-based mobile communication framework for handling emergencies	RFID for emergency (ROY) approach for enhancing system's efficiency during emergency	Data	No	RFID	Researchers	Response, recovery
Supporting urban emergency response and recovery using RFID	RFID embedded portable devices and tags for gathering, storing, and sharing information	Sensed data	Yes	RFID	Researchers	Response, recovery
On-site information systems design for emergency first responders	How emerging technologies such as WSN and RFID might enable on-site dynamic information	Sensed data	No	RFID, WSN	Researchers	Response
Emergency management system based on WSID network	Emergency management system based on WSID to solve the inconvenience of aid persons and goods management in disasters	Data	Yes	WSN, Zigbee	Researchers	Response, recovery

Web-of-Objects-based context aware emergency fire management systems	WoO-based system integrated with virtual objects (ViO) interconnected in semantic ontology model	Sensed data	Yes	WSN, RFID	Researchers	Preparedness, response, recovery
Architectural design of IoT in logistics management for emergency response	IoT-oriented service architecture for logistics management which is concerned to emergency response	Resourced data	No	RFID	Researchers	Preparedness, response
A mobile disaster management system using the android technology	An android application to facilitate and take geographical locations of people directly or via sms and determine optimum route	Resourced data	Yes	Wireless mobile technology	Researchers	Response, recovery

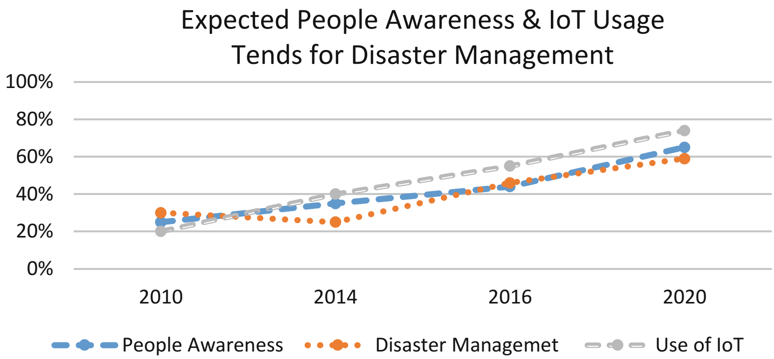

Fig. 27.4 Current and expected trends related to disaster management

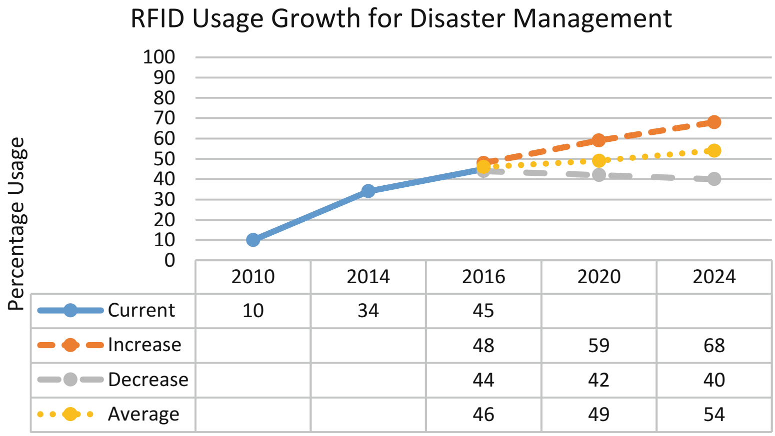

Fig. 27.5 RFID usage growth in upcoming year

27.5 Conclusion

In this paper, we described the disaster management and its different phases, through which we can reduce the impacts of disasters. The Internet of Things, an evolving standard, can add a lot in this context. Major technologies of IoT, such as WSN, RFID, GIS, and GPS, are described, and we did a complete review of the existing use of these technologies in disaster management and at which level they are contributing. A detailed analysis is performed, by observing different approaches, their contribution, and supporting phases. On the basis of that evaluation, RFID is the most common and valuable technology for managing disasters. By reviewing all the work done in this field and the percentage of use of technologies and their contributions, it is predicted that disaster management would increase in upcoming years as people's awareness and usage of IoT would increase. In the future it is aimed that on the basis of this analysis, a complete IoT architecture for disaster

Fig. 27.6 Taxonomy of technologies used for disaster management

management will be proposed, in which the main focus will be on the shortest time span in which a disaster alert can be reached to all concerned authorities and the use of RFID for tracking all the "things" combined in a disaster managing environment.

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