# Communication Between Emergency Medical System Equipped With Panic Buttons and Hospital Information Systems: Use Case and Interfaces

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***Abstract*—For patients with a risk of out-of-hospital emergency situation quickness of the first aid provision is essential. Emergency medical services equipped with the "panic button" are aimed at reduction of the time of first aid provision. The further improvement of such services can be achieved by their communication with healthcare information systems deployed in hospitals. Such communication can be used to retrieve past medical history of the patient directly during the first aid provision, find an appropriate hospital for the patient's conveyance, automatically transmit the clinical handover information etc. This paper is devoted to identification of typical use case of communication between emergency medical services equipped with the "panic button" and healthcare information systems, and analysis of possible ways of organization of such a communication.**

## I. Introduction

Emergency medical services (EMS) are intended to provide out-of-hospital medical care to the people in emergency situations related to sudden illness (e.g., stroke or hypertensic crisis) or injury. In such situation quickness of the medical assistance is of high importance, e.g., according to [1] even reduction by a minute increases chances of the patient's survival by 24 % in case of the cardiac arrest.

In order to achieve such a reduction for patients with chronic deceases prone to get into an emergency situation there are dedicated services based on the emerging e-Health paradigm ([2], [3]) that provide such people with a special device containing the "panic button" (or a common mobile phone with a special application installed) that has to be used by the patient in case of emergency. When the button is pressed a dedicated emergency service processes the request and sends a paramedic crew to provide first aid to the patient. In order to distinguish EMSes involving the concept of the "panic button" from general emergency medical services we refer to them as pbEMS in this paper.

Further improvement of pbEMS can be made via its integration with healthcare information systems (HIS) deployed in hospitals. Transmission of the information about the patient's conditions from the ambulance crew to HIS can make hospital staff more ready for treatment. For example, even notification of the hospital staff that the transported by the ambulance crew patient has a stroke can positively affect his/her treatment [4].

Another issue that can be addressed by pbEMS-to-HIS communication is corruption of data about the patient's health state during the clinical handover [5]. In this case automated transmission of such data from the ambulance crew directly to HIS would prevent them from corruption due to mistakes caused by emergency situation or lack of communicative abilities of the hospital's staff.

However, although the topics related to pbEMS research and development gains popularity nowadays, there is a lack of analysis of pbEMS-to-HIS communication in the existing scientific literature. This was a motivation of this study that is devoted to identification of typical use case of pbEMS-to-HIS communication and analysis of possible ways of organization of such a communication.

The rest of the paper is organized as follows. Section II provides an overview of healthcare information systems. It is intended to give a view on the information that can be utilized by pbEMS to improve quality of service. In Section III we elaborated four organizational schemes that can be adopted for pbEMS-to-HIS communication and illustrated them using examples from existing scientific papers on pbEMSes. Section IV provides a common use case for pbEMS-to-HIS communication along with subsidiary variants that can alter some implementation details of such communication in practice. In Section V we subdivided pbEMS-to-HIS communications into separate categories and for each category considered possible interfaces and tools for implementation. Section VI summarizes the results of the paper.

We would like to mention that in the study we did not address security and privacy aspects of the pbEMS-to-HIS communication. Although this topic is essentially important for systems in question, its scope and complexity require a thorough research that deserves to be considered in a separate paper.

## II. Healthcare information systems

Historically HISes are deployed in the medical facilities in order to automate their operations and therefore improve the quality of healthcare provision to patients. These systems facilitate both the administrative work of the hospitals and the patient treatment process. This section gives a brief overview of currently deployed and developed HISes, their key components, and the data they manage.

The Shimane University Hospital has an advanced HIS that serves about 350 doctors and 600 beds via wireless infrastructure that can transmit voice communications as well

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as data [6]. This HIS not only manages internal processes in the hospital, but provides patient's data to other medical facilities when the patient is transferred there for a treatment. This is achieved through a special component that interacts with the local inner-regional collaboration system.

The core of the system is the electronic patient record system that collects all the information about the patient's health state (a problem description by the patient, medical examination documents, clinical paths, etc.), operations performed by doctors (examination, operation, meal, etc.) as well as nurses (care plan, nursing order, etc.). All other subsystems support operation of separate units of the hospital and use the record system to store and retrieve required data.

In [7] the authors describe Inpatient Information System (ISS) deployed in the National Taiwan University Hospital that manages 2 200 beds and 7 000 patients every day. This system was developed as a replacement for the deprecated mainframe-based solution that was not able to keep up with the workload and changing requirements. The paper mainly focuses on the architecture of the system including core components, data transmission mechanisms, and the way they work together to provide reasonable response time for end users of the system.

The system includes the following core components that manage patient data: Healthcare Information System (HIS), Laboratory Information System (LIS), Picture Archiving and Communication System (PACS), Radiology Information System (RIS). These systems are the basis for another systems that provide concrete functions for end users including IC Card System, Print System, Order Management, Billing Account, Diet System, CPOE. The last system allows a medic to prescribe medication, a pharmacist to dispense them, a nurse to process the request, and a clerk to bill the patient.

In [8] a cloud-based model for HIS organization is proposed. The paper discusses distinctive properties of cloud-based solutions and requirements for successful integration of several services. The proposed cloud infrastructure is currently does not exist, but it should be implemented as a software-as-a-service solution that can be managed by the government and used by municipal hospitals.

The system may include up to twenty modules that can be unitied into two groups: process support components, each of which manages a specific part of the hospital department, and service providers that facilitate the work of the first group. The list of service providers include Electronic Medical Record (EMR), Electronic Nursing Record (ENR), Personnel Staffing and Scheduling Information System (PS), Decision Support Systems (DSS), and others.

All of the reviewed HIS restrict access to the medical records of the patient being treated according to users' roles. For example, a laboratory worker only needs to receive request to perform an analysis on the patient, check previous related records, and add results to the history. This is also true for other parts of the system that manage administrative processes.

Another common feature of the systems is their modularity—every HIS consists of a set of modules that interact with each other. These features combined should allow HIS to provide medical data to external services such as

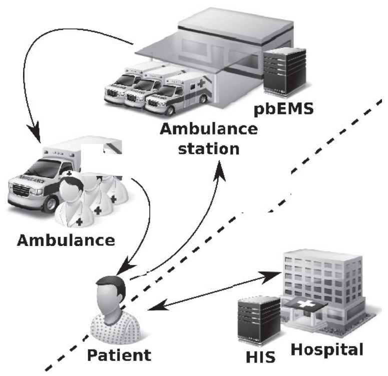


Fig. 1. Autonomous operation of pbEMS and HIS

pbEMS via a special module. This module would provide only those parts of records that are required by the other party.

## III. Organizational Schemes of pbEMS-to-HIS Communication

A set of factors essentially influence the way pbEMS and HIS can communicate with each other.

The first one is the availability of medical facilities in the area where these services operate. A small town cannot maintain several hospitals, on the other hand several specialized clinics and many general hospitals generally present in a megalopolis.

The second factor is the ownership of the services. They may belong to the government, a concrete hospital or supported by a commercial structure. If services belong to the same organization they are more likely to be interoperable than services from different vendors.

The third factor is the technological state of communication infrastructure in the area. The more robust, pervasive and effective data transmission enables more distributed, diverse communication between the systems.

Taking these factors into account we identified four schemes of interaction between pbEMS and HIS systems:

1) pbEMS functions autonomously having no connection to HIS (Fig. 1).
2) pbEMS is created on top of HIS deployed inside a hospital being a module/plug-in of HIS (Fig. 2).
3) pbEMS is an independent system that communicates to HIS deployed in a hospital (Fig. 3).
4) pbEMS is an independent system that communicates to a cloud of HISes deployed across several hospitals (Fig. 4).

An example of dedicated pbEMS using the first scheme with no connection to any hospital's HIS is described in [9]. The system includes an Emergency Dispatch Centre that accepts alarm signals from GPS-equipped patient's devices and dispatches paramedic teams. In case of necessity such a team conveys the patient to a hospital. This is a base way of pbEMS organization that cannot benefit from possible integration of pbEMS with HIS.

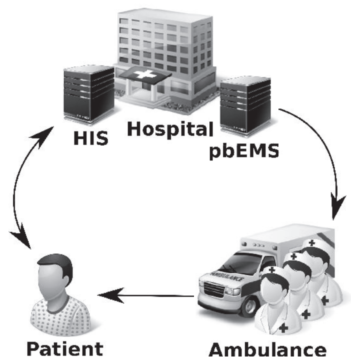


Fig. 2. pmEMS as the extension of HIS

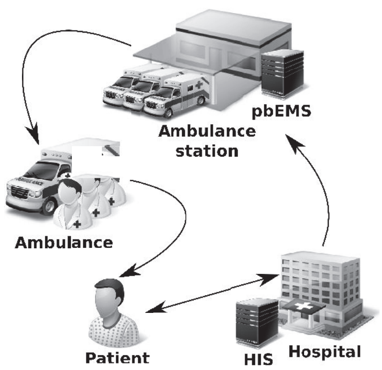


Fig. 3. pmEMS is the external service to HIS

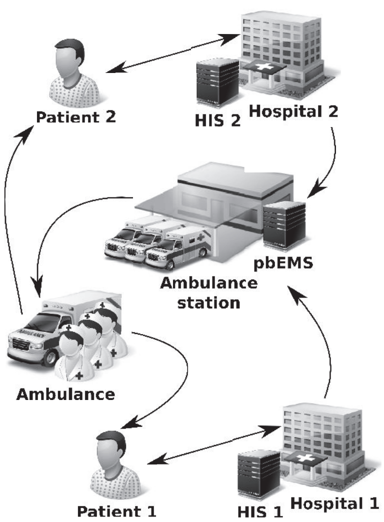


Fig. 4. pmEMS is the external service to cloud of HISes

pbEMS developed according to the second scheme can be found in [10]. The system described there is called mPHASiS. It uses vital sign sensors attached to a patient to automatically detect appearance of an emergency situation. Communication with HIS is made via SOAP protocol that allows to use patient's electronic medical card (EMC) during hospitalization and other HIS services. Unlike the previous considered pbEMS, this system does not dispatch ambulance teams as it is supposed to be a responsibility of the host hospital.

In the next scheme pbEMS is independent from HIS, therefore it has to dispatch ambulances itself. An example implementation called CMES (Comprehensive Medical Emergency System) is described in [11]. The alarm signal is sent using Emergency Requester Device (a special application installed on the patient's mobile phone). The ambulance crews are dispatched semi-automatically based on polling current location and status of the crews. Communication between pbEMS and HIS is used to (1) retrieve information about the patient's past medical history; (2) find the nearest hospital with beds and appropriate equipment available; and (3) send all the information about the patient's health state and the medical assistance essential for clinical handover to the hospital. The authors of the paper suggest using the Health Level 7 (HL7) framework (http://www.hl7.org) to exchange medical data between pbEMS and HIS.

The last scheme in the proposed classification presumes communication of pbEMS with a cloud of HISes. Such a scheme can be useful either in case when pbEMS is provided by a third party company and has to communicate to multiple hospitals across the city, or in case of a lack of properly qualified personnel in local hospitals and/or paramedic crews. The latter is especially important for developing countries, and an example of closely related system for Indian rural areas can be found in [12]. The main idea of this paper is a Doctors association that can be used to find doctors available online to analyze the patient's condition after receiving the data sent from the ambulance and suggest how to provide medical assistance before conveyance of the patient to the hospital. Such a scenario definitely requires communication of pbEMS with a HIS cloud and details of such a communication should be thought through thoroughly.

## IV. Use Case

Based on the organization schemes presented in the previous section we formulated the most common use case of pbEMS. The first part of the scenario that describes provision of the first aid to the patient is shown in Fig. 5. The second one that covers conveyance of the patient to the hospital is shown in Fig. 6.

1) pbEMS is notified about an emergency case.
2) pbEMS finds and assigns an ambulance for the case.
3) pbEMS retrieves medical records of the patient from HIS and transfers them to the ambulance.
4) Paramedics study records, reach the patient and provide him/her the first aid.
5) During the procedures the paramedics collect all necessary information including vital signs, applied procedures, medication etc.

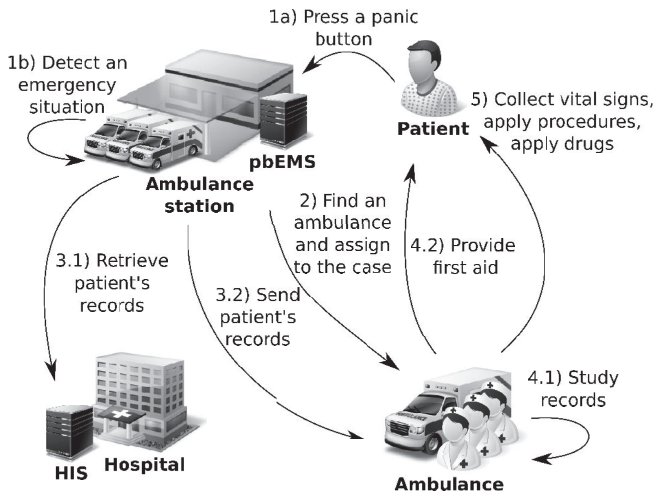


Fig. 5. The provision of the first aid to the patient

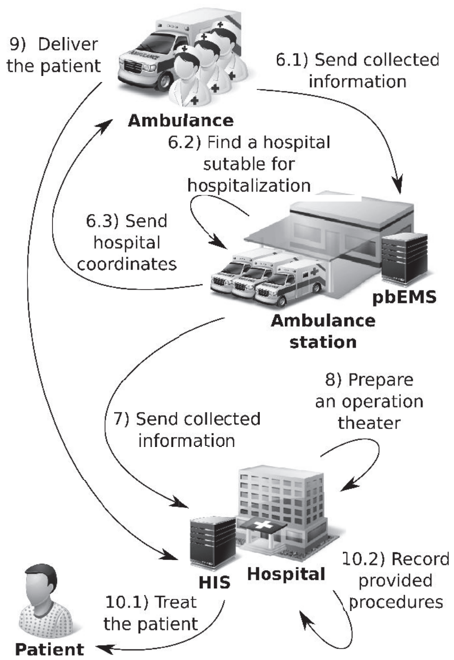


Fig. 6. Transportation of the patient to the hospital

6) Based on the collected data and request from paramedics pbEMS finds a hospital suitable for hospitalization and treatment of the patient; pbEMS makes appropriate arrangement through HIS.
7) pbEMS provides the hospital with all information that was gathered during the provision of the first aid to the patient.
8) Upon agreeing on hospitalization hospital staff begins to prepare an operation theater to provide treatment to incoming patient.
9) The ambulance conveys the patient to the hospital.
10) The hospital staff treats the patient and records all applied procedures in HIS.

This use case can have a plenty of variations when implemented in particular pbEMSes. The most important examples of them would include the following.

Regarding step 1 there are possibilities that a patient presses the panic button him/herself or a monitoring system based on vital sign sensors automatically detects an emergency situation. Such an automatic detection can be managed by pbEMS itself (as shown in the reviewed paper [10] above) or can be a part of a hospital monitoring system. The latter case implies that the emergency signal could come from HIS. However, such cases are mostly related to in-hospital monitoring and do not include pbEMS in the sense we consider it [13]. That is why we do not cover them in this paper.

In case of the manual panic button activation there could be an intermediate step between steps 1 and 2 directed at prevention of possible false alarms. For example, pressing the panic button could entail establishing the voice communication between the patient and an pbEMS operator who makes sure that the emergency situation has really occurred.

On step 2 pbEMS can either dispatch an ambulance itself or send a request to HIS to perform an assignment. The choice depends on whether pbEMS has its own ambulance fleet or not. The latter case requires additional communication between pbEMS and HIS and usually implies that pbEMS is implemented on top on HIS that dispatches the ambulances of the hospital where it is deployed, because otherwise it would leave to pbEMS too little responsibilities to be effectively implemented as a separate system from the business perspective.

On the same step pbEMS must prioritize ambulances between incoming requests: some cases require immediate reaction (e.g., a heart attack), while others may be hold on a wait for several additional minutes. The choice must solely depend on a severity of an emergency situation that can be either stated by the patient or determined by an analysis of sensor data. In order to facilitate the decision phase, pbEMS must include the suggestion mechanism that would provide criteria to make prioritization between different requests. For example, in [14] the authors propose to track the severity of event by checking whether other public services like a police are used to handle the emergency situation.

In rather rare situations on step 4 the paramedic crew can consult a remote doctor using technologies of telemedicine. It looks like it is not a typical scenario because usually the paramedic crew performs only typical procedures to provide the first aid leaving the treatment to the hospital staff (which can use telemedical means for that purpose if required). However, using remote consultations by paramedic crew is described in [12] that shows that such a scenario is not unthinkable.

During step 6 pbEMS is required to coordinate actions with many HISes of hospitals that are able to accept the patient and to determine where he/she may be transfered as soon as possible. According to [9] pbEMS must at least maintain the registry of hospitals that include their geographical coordinates as well as a list of their specializations. The algorithm that pbEMS uses to choose a hospital should also consider their current workload that can be retrieved by polling all registered HISes. If a set of hospitals use a common cloud-based HIS then

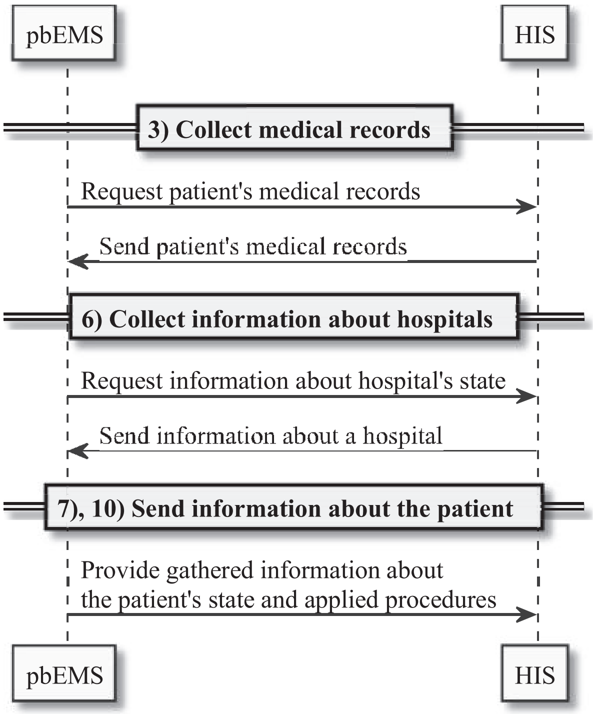


Fig. 7. Data transmission between pmEMS and HIS. The numbers in the figure corresponds to the steps of the use case in Section IV

the task of finding an appropriate one for the patient might be implemented as part of that solution as described in [15].

## V. Possible Interfaces between pbEMS and HIS

As follows from Sections III–IV the most common operations that require communication between pbEMS and HIS include:

- Retrieval of information about the patient's past medical history from HIS by pbEMS;
- Search for the nearest hospital appropriate for the patient's hospitalization;
- Sending the information about the patient's health state and the provided medical assistance essential for clinical handover from pbEMS to HIS.

The order of data transmission in accordance with the use case is shown in Fig. 7.

In this section we consider these types of communication in more detail to find out and analyze concrete interfaces and technologies that can be used to establish such communications.

### *A. Patient identification*

Before considering the aspects of pbEMS to HIS communication it is worth briefly mentioning the issue of patient identification in HIS. The importance of patient identification is due to necessity of electronic medical card retrieval that is usually done from HIS being external to pbEMS. Therefore HIS usually may not provide access to such sensible information without authorization.

We would like to stress that having the "panic button" on a personal emergency device (or in a mobile application) in pbEMS is a crucial feature for patient identification. Because of it each emergency request to pbEMS can be regarded as personalized. And this is not always true when the emergency signal comes to a dispatcher via common channels, such as a phone call.

In the simplest case having an alarm signal from a personal emergency device is enough to identify the patient and to get access to the required data based on contract between pbEMS operator and the hospital where HIS is deployed. In this case the patient shall permit pbEMS to get access to her sensible data beforehand. The actual authorization can be done using one of existing authorization frameworks developed to manage shared access to electronic health records, e.g., the one described in [16].

This can be insufficient in case of necessity to access a cloud of several HISes because the rules to guarantee privacy can be rather strict and complicated in such environments. Usually it is essentially based on roles and involve vertical partitioning of medical data to guarantee retrieval of the minimal required amount of information shared to the third party [17].

### *B. Retrieval of past medical history*

When talking about retrieval of the past medical history in context of pbEMS, it is also presumed that HIS use some sort of an electronic medical record (EMR). EMR contains all data that relate to a concrete person's health including a patient history, a patient problem list, physician clinical notes, a list of attended procedures, comprehensive list of patient medications and allergies [18]. The term electronic health record (EHR) refers to a broader knowledge of the patient's health that can be composed out of a set of EMRs that different medical services manage [19].

Though EHR contains a comprehensive amount of information, only a small part of it is required during the provision of the first aid. The needed data subset may include a list of chronic deceases, a list of allergic reactions to medications, a list of prescribed medications and therapies. Additionally, for a patient with a chronic decease an emergency is often associated with the exacerbations of the decease. The knowledge of this fact may significantly reduce the time paramedics needed to provide the first aid because all required equipment and medicine will be ready for application before the arrival of the ambulance.

During the provision of the first aid it is common practice to give the patient a strong medicine to stabilize his/her condition. If paramedics must use such a medicine then they must be sure that the person does not have an allergic reaction and if he/she does, they must use alternative medicine that will not cause a severe reaction. Another aspect to be aware of is the compatibility of medicine that person takes during his/her current treatment with the emergency one. The paramedics are likely to choose the correct medicine if they aware of both factors.

The concrete contents of the medical record send to the paramedics must be developed by medical specialists and can not be constrained by the previously stated topics. Thought it is clear that a special view of the full EHR is needed to be present during the provision of the first aid due to the excessive amount of data inside the record and due to special requirements of the case.

One of the core issues that can prevent the use of the patient's EHR is the absence of a common infrastructure to support data extraction from different HISes. Though the positive impact of EHR for a patient is obvious, the current state of development of HIS and interoperability standards do not allow to easily form the EHR record. Currently there are a lot of research efforts that are targeted to overcome the stated problems and enable data exchange between medical systems [20]. Though there are examples of implemented data exchange protocols between different instances of the same system [21].

Therefore in the current situation pbEMS must implement data aggregation functions independently and connect to interfaces of HISes. In order to achieve this developers must overcome the lack of content standards, the diversity of terminology used to represent data inside documents and the absence of common protocols to enable secure and reliable communication [22]. One way to overcome this problem is to develop interoperability profiles for each systems that would allow to unambiguously represent data from different systems. One of the promising solutions is to use ontologies to represent terms and provide mapping between different documents and terms [23].

### C. Search for nearest appropriate hospital

In most cases of emergency situations the paramedic crew has to deliver the patient to a hospital. In the most simplest case the patient is delivered to the nearest hospital. However, more sophisticated approach can be used to improve quality of the medical help provided to the patient in there. Particularly, according to [11] the following factors can be taken into account when selecting the hospital to deliver the patient:

- location of the hospital;
- specialization of the hospital;
- availability of beds, equipment, and other hospital's resources.

Considerations about the hospital location can be utilized by pbEMS itself based on the ambulance geolocation, the list of the available hospitals and sometimes even the traffic congestion (using external services, e.g., Google Maps). The same is true regarding the hospital specialization: the appropriate one can be selected automatically based on the preliminary diagnosis made out by the paramedics.

On the contrary, for getting information about availability of beds, equipment, and other hospital's resources there should be a special interface between pbEMS and HIS. For example communication can be organized according to the following schemes:

1) pbEMS sends information about the patient's diagnosis and requirements for his/her presumable treatment to HIS. In response HIS informs pbESS whether the corresponding hospital is ready to receive the patient;
2) pbEMS polls all available HISes for information about available resources and selects the appropriate hospital on its own using on all retrieved information.

Which scheme is used in a particular case mostly depends on the used HIS and information they are ready to provide. Obviously, many more other schemes may exist to solve the task of the appropriate hospital search.

Unfortunately, at the moment there are no standards and protocols that provide uniform look to the information about available hospital beds and treatment capabilities. It means that for each concrete HIS access to such information should be implemented in specific way using dedicated HIS plugins, SOAP or REST services and other means. Obviously, it implies restrictions on efficient pbEMS-to-HIS communication when searching for nearest appropriate hospital, but there is a hope that with spreading of pbEMSes the required standardization measures would be conducted.

### D. Sending clinical handover information

During the transportation to the hospital and handover procedure paramedics must provide all collected data on vital signs and lists of applied procedures and drugs to the HIS. From the organizational point of view it can be said that the ambulance represents a department of the hospital that provides services to the patient and records them into the hospital's HIS, though being operated by the external organization and outside their internal network.

This procedure resembles in many aspects the retrieval procedure described in V-B: two organizations must agree upon data representation standards, organize secure channel for data transmission and provide all required data. But they differ not only in the direction of data transfer, but also in the amount of data and requirements for continuity. During the handover procedure paramedics must provide not only a brief summary of their actions, but a complete log of patient vital signs that were logged by the sensors. This data may be essential during the final steps for stabilization inside the hospital.

Data may be provided to the hospital either on arrival of the ambulance to the hospital or during the transfer of the patient. The fist scheme matches the classical approach on communicating data between paramedics and the hospital staff. When the ambulances arrives to the hospital paramedics provide brief summary on the condition of the patient and then transfer data into HIS. The latter approach assumes that the summary is automatically generated by HIS when data comes to the system and doctors may retrieve any data whenever they want, therefore reducing the workload on the paramedics and providing all information to doctors actively.

The recent efforts to unify emergency information to improve medical systems interoperability based on the HL7 standard [24] can be essentially useful for sending clinical handover information as they lower the difficulty of implementing data converters between pbEMS and HIS, allow for a clean and unambiguous representation of applied procedures. If both systems use the same format to represent data describing the emergency, then it extends the way paramedics may interact with HIS including a scenario when they directly transfer data to HIS without connection with pbEMS.

## VI. Conclusion

In the paper we identified typical use case of pbEMS-to-HIS communication and analyzed possible ways of organization of such a communication. The main outcomes of our research can be summarized as follows:

- pbEMS should construct the patient's EHR out of data contained inside several HISes and transfer it to paramedics. To do so, developers have to overcome the issues of patient identification and data representation in different HISes.
- pbEMS should negotiate the hospitalization procedure with the hospital. It requires access to current state of the hospital facilities including availability of both staff and equipment.
- pbEMS should accumulate and transmit data about patient state during the provision of the first aid and transportation to the hospital. Developers must negotiate a common standard on information representation that can be used in all targeted HISes.

Unfortunately, currently existing HISes usually do not provide any services to access internal information, and even if they are present, they usually have incompatible interfaces. Regarding the medical data representation, the HL7 standard solves most of the data-level interoperability issues, whereas the absence of industrial standards on data manipulation essentially restricts possibilities to organize efficient pbEMS-to-HIS communication.

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