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DESIGN AND IMPLEMENTATION OF EFFICIENT INTEGRATED SYSTEM FOR PHYSICAL MEDICINE WITH CENTRALIZED MANAGEMENT OVER COMPUTER NETWORK

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Abstract. The cabinets for physical therapy are provided with various devices which shorten the time needed for patients' recovery and healing. A typical physical medicine cabinet has tens of stand-alone devices for different purposes. These are the devices which perform biostimulation using diadynamic or interferential electrical currents, ultrasound waves, vacuum impulses, electromagnetic fields, etc. The aim of this paper is to present hardware and software components, and developed network protocol for integrated system of devices for physical medicine, based on the existing products of Elektromedicina company, with key feature that allows the devices to be centrally managed and monitored. This paper addresses the system's architecture, user interfaces both for devices and centralized server console, network protocol for communication between devices and centralized management station, the scheduler, and the therapy procedure within the system. It will be shown that the efficiency of the integrated system, measured in the time-per-patient and patients-per-day, compared with the efficiency of regular physical therapy cabinet is increased by more than 20%.
Keywords: Optical networks; semi-conductor; centralized management station; integrated system.

1. Introduction

Physical therapy or physiotherapy (sometimes abbreviated to PT) is a health care profession primarily concerned with the remediation of impairments and disabilities and the promotion of mobility, functional ability, quality of life and movement potential through examination, evaluation, diagnosis and physical intervention. It is carried out by physical therapists and physical therapist assistants. It includes the use of physical measures, activities, and devices, for preventative and therapeutic purposes [1]. Well-known manufacturers of such devices are Gymna-Uniphy,

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Shock Master, Enraf Nonius, and Siemens, while Elektromedicina d.o.o. is the manufacturer with the highest number of sold devices in Serbia. Typical cabinet for physiotherapy is usually equipped with different types of devices which shorten the time needed for patients' recovery and healing, each specialized for particular disability.

The devices for physiotherapy are usually stand-alone devices having the applicator at one side, which is attached to the patient and uses diadynamic electrical currents, interferential currents, ultrasound waves, vacuum impulses, or electromagnetic fields in order to apply the therapy, and operational controls at the other side for setting up therapy parameters. Usually the patients are sequentially treated with different physical therapy devices, applying different procedures for prescribed period of time. Typical scenario for the patient to be treated is to apply several different methods in one day, and to repeat the same procedure every other day for one or two weeks [1]. Depending on the treatment, and development of patient recovery, device parameters are in the most of the cases set manually on each device before each treatment. This process can consume time and lead to less efficient usage of the cabinet resources.

A lot of efforts with different goals have been done in recent years to interconnect different medical devices [2], [3]. The goals are mainly oriented to data acquisition and alarming of hazzard situations. In the most of the cases developed systems are proprietary and patented [4], [5]. However, there is a set of open standards for network communication of medical equipment, such as X.73 [6], [7].

The goal of this paper to present a new generation of devices for physical medicine, based on existing products of Elektromedicina company. Key feature of the new generation of devices is to allow the device to become a networked module in the centralized system for physical therapy. The devices should be integrated into a centralized system for network management and data acquisition, based on the adjusted modification of open X.73 standard [6], in the same manner regardless of the type of the device. The functional features of the previous generation in the sense of standalone operation should be retained. The aim of the integrated system is more efficient usage of resources in the physiotherapy cabinet by reducing the time required for the identification of the patient and setting up the initial parameters on the particular device, which is achieved by centralized management over computer network.

This paper focuses on the design of the system's architecture, design and implementation of the protocol for network communication, and the design of user interface for both devices and the centralized control station, while addresses the patient treatment process within the cabinet through the process of patient identification and therapy scheduler. Design aspects of the integrated system regarding remote semi-automatic or automatic setup of parameters and devices control, the ability to automatically record the progress of the treatment, and new user interface and management console for centralized control station will be presented in detail. Automatic control of the devices refers to setting of treatment parameters on the specific device from the centralized location in the scheduled time for the patient.

The paper is organized as follows: Section 2 gives a brief overview of Elektromedicina's previous generation of physical therapy devices and discusses the requirements for the new generation of the devices. In Section 3 integrated system's architecture is presented in detail, while in Section 4 new user interface for the new generation of physical medicine devices is presented. Section 5 is devoted to the network communication protocol, in Section 6 user interface of the centralized management console is presented, in Section 7 the simulation and implementation results are discussed, while in Section 8 the concluding remarks are given.

2. Physiotherapy Devices

Typical cabinet for physical medicine contains numerous standalone physical therapy devices of different types. It is common for the patient to be treated by different devices, thus the cabinets for physical medicine are usually equipped with various types of devices [1].

The block diagram of a device for physical therapy, regardless of its type, is shown in Fig. 2.1. The operator attaches the applicator to the patient's body and sets the therapy parameters using the user interface, as it is shown in Fig. 2.1. The type of the applicator depends on the type of the device. Some devices, which use different types of electrical current for the treatment, are equipped with electrodes, while some devices use vacuum pumps, electrical coils, and ultrasound applicators.

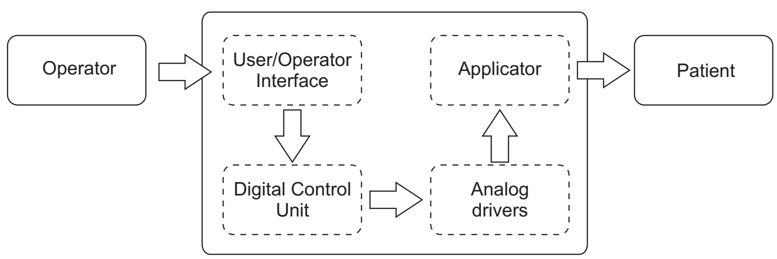

FIG. 2.1: The block diagram of a device for physical therapy

There are a lot of manufacturers of physical therapy devices world wide. The Faculty of Electronic Engineering, University of Niš, Serbia runs the project *"Integrated Intelligent System for Physiotherapy - IISP"*, in the cooperation with Elektromedicina d.o.o. Niš, which is supported by the Serbian Ministry of Education, Science and Technological Development (Project TR32012), with aim to develop a new generation of physical therapy devices that will have the ability for interconnection and remote control, management and acquisition of data. Six different types of Elektromedicina's devices that are included in the IISP project are: Eksposan^{TM}, Magnemed^{TM}, Intermed^{TM}, Vakumed^{TM}, Diaton^{TM} and Sonoton^{TM} (Fig. 2.2). The devices are specialized to treat different parts of human body using different physical agents. Each device allows an operator to choose an initial set of therapy parameters, and to monitor and change their values in the course of the therapy.

FIG. 2.2: Types of Elektromedicina's devices that are included in the IISP

The main goal of the IISP project is to develop the Integrated Centralized System for Physical Medicine (ICSPM), through redesign of existing physical therapy devices of Elektromedicina d.o.o company by introducing networking capabilities, providing interconnectivity for the support of system integration. The system should send the parameters of the treatment automatically to available device of particular type after successful identification of the patient, enabling at the same time continuous monitoring of the treatment. Centralized system should contain a database of patients' records with predefined therapies, and the notes on the recovery progress.

The main requirements are:

1. the devices should have an extension which allows them to be monitored and managed by the unique control station within the ICSPM;
2. ability to manually set the parameters on each device, or automatically over computer network from centralized location;
3. the therapy planner and scheduler;
4. a database with patients' records, with scheduled treatments, treatments history and device parameters for each treatment;
5. common user interface for all device types.

Having in mind the significant number of produced devices by Elektromedicina company, decreasing of costs for transition to the new technology becomes the issue of the great importance. The cost-effectiveness led us to reusing of analog drivers and applicators (Fig. 2.1).

In order to fulfil the requirement for the new user interface on the devices, as well as the requirement related to the ability to connect the devices to local Ethernet network, microcontroller-based logic was attached to the existing analog drivers. The block diagram of the ICSPM device is shown in Fig. 2.3. Gray shaded blocks in Fig. 2.3 represent modules which are added in order to fulfil the requirements. Chosen microcontroller is Microchip PIC18F877 J60, with built-in Ethernet controller.

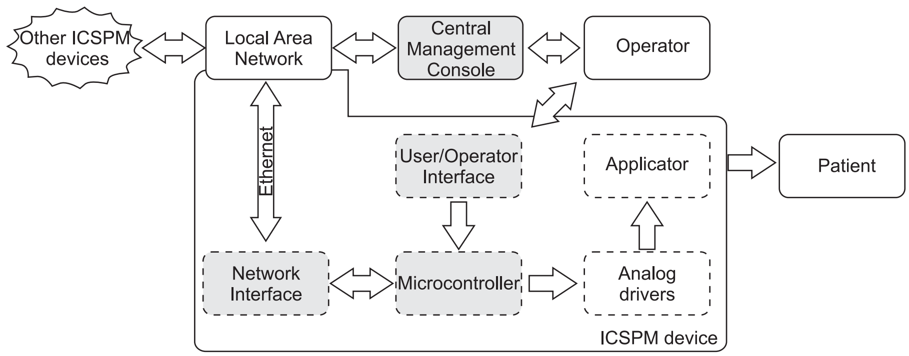

FIG. 2.3: The block diagram of an ICSPM device

The user/operator interface, shaded in Fig. 2.3, is completely redesigned in order to provide the possibility for setting of device parameters for treatment, as well as new parameters related to network operation.

3. Integrated System for Physiotherapy

According to the requirements, the integrated system should consist of the devices equipped with networking module, central management station, and the database. The ”actors” in the system, speaking in the UML context, are the patient and the operator, as it is shown in Fig. 3.1, which illustrates the UML component model of the system.

The component model (Fig. 3.1) shows the system's components, including their internal structure. The physical medicine device from Fig. 3.1 has analog drivers that are inherited from the previous generation of Elektromedicina's devices. The drivers are used to drive the applicator and apply the therapy. As it is shown in Fig. 2.3, the devices are equipped with microcontroller for the implementation of network protocol and the user interface. In order to be able to process several different tasks in parallel, such as sending and receiving packets over computer network, displaying messages to the user, process user inputs, and drive the applicator, the microcontroller runs the real-time operating system (RTOS), which is shown as a subcomponent in Fig. 3.1. For the chosen PIC microcontroller RTOS named OSA is employed [8].

OSA is RTOS for Microchip PIC-controllers PIC10, PIC12, PIC16, PIC18, PIC24, dsPIC, for Atmel AVR 8-bit controllers, and for STMicroelectronics STM8 [8]. RTOS allows the programmer to primarily focus on problem-oriented tasks (algorithmic, mathematical, etc.). All secondary tasks are performed by OSA's kernel, such

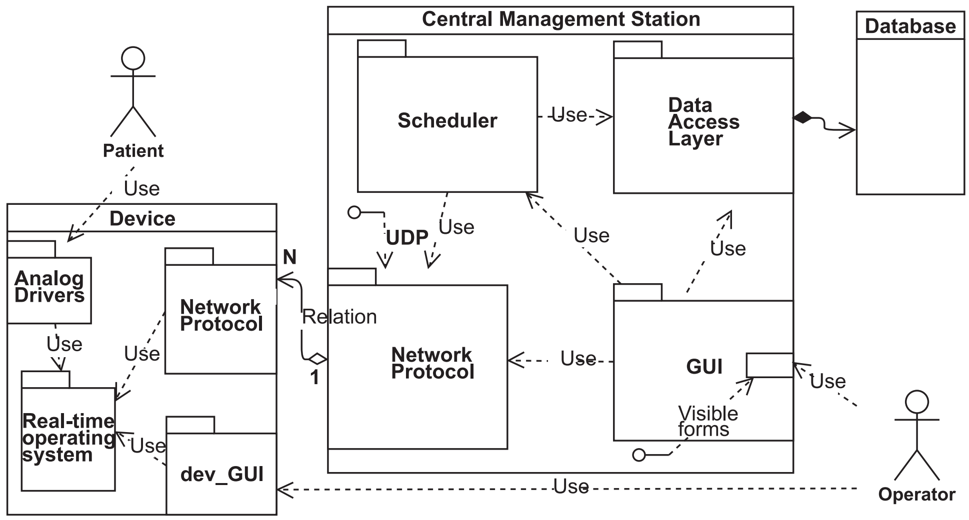

FIG. 3.1: The component model of the integrated system for physical therapy

as switching between parallel tasks, checking timeouts, counting delays, finding the ready task with the highest priority and executing it, data exchange between different tasks using semaphores, messages, queues etc.

All subcomponents of the device component from Fig. 3.1 are using services of RTOS OSA in order to be executed as concurrent tasks. These include the analog drivers, the network protocol, and the user interface, denoted as dev_GUI in Fig. 3.1, which has two roles executed as separate RTOS tasks: handling the user input, and displaying the messages to the user.

The Central Management Station (Fig. 3.1) is organized around its Graphical User Interface (GUI). The GUI uses the services of the scheduler component, which allows user to plan and schedule therapies. It also uses the Network Protocol component in order to pass the commands received from the operator to the devices. The Data Access Layer (DAL) serves as an abstraction of the database, providing the required functions to the scheduler and the GUI.

The role of the operator and the patient within the system, and the interactions between them and the system's components are presented by UML sequence diagram shown in Fig. 3.2. In the coordinate system of the sequence diagram the abscissa stands for the actors and the system's components, while the ordinate stands for the elapsed time.

The sequence diagram in Fig. 3.2 is divided in two sections, and each of them is divided into few subsections for the further reference. The first section stands for the first patient's visit, and it describes the process of patient registration (section 1.1 in Fig. 3.2) and initial scheduling of therapies (section 1.2 in Fig. 3.2). As it can be seen from Fig. 3.2, after the operator identifies the patient and obtain the

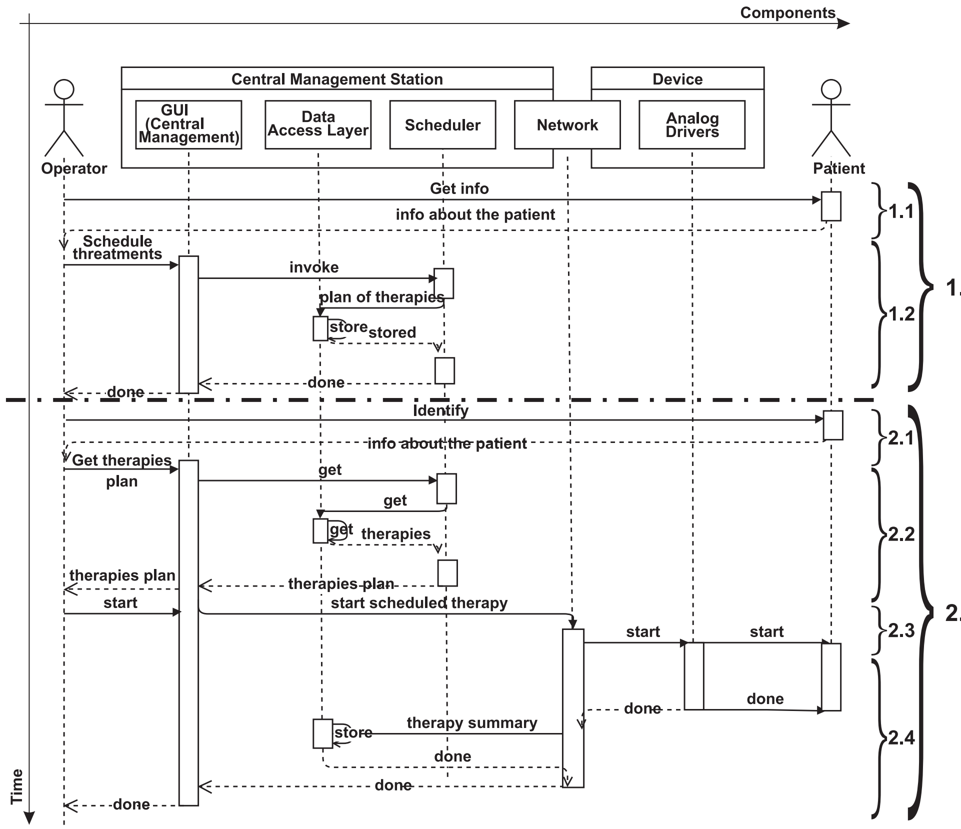

FIG. 3.2: UML sequence diagram of patient treatment within the integrated system

required patient's data, the operator records the data and schedules the treatments using the GUI component.

The second section in Fig. 3.2 describes the process that is usually repeated every few days for each scheduled treatment, starting with the first patient's visit (section 1 in Fig. 3.2). The process of patient identification is query-response between the operator and the patient (sec. 2.1, Fig. 3.2), after which the operator gets therapies plan from the system (sec. 2.2) and starts the therapy using the GUI (sec. 2.3).

4. User Interface of the new generation of Physical Therapy Devices

The therapy within ICSPM can be setup and started both from the device and from the central management station. As there is usually a barrier in acceptance of new computer systems and technologies by medical staff, part of the research was devoted to the ergonomics of new system. The central part of the Human-

Computer Interaction (HCI) research was devoted to methodologies and process for interface design and implementation, quality estimation, and development of model for intuitive interaction. In order to overcome the barrier for the acceptance of the ICSPM devices by different types of medical staff, the common user interface for the devices is designed. The interface is driven by microcontroller, as it is shown in Fig. 2.3. The chosen interface is 2x16 character display, and a set of five common keys.

Having in mind that there are six different types of physical medicine devices with different functions and different parameters (Fig. 2.2), and that all of them should be supported by a single user interface, the starting point in the interface design was analysis of the current user interfaces. Table 4.1 gives the summary of keys provided on the front panel in the previous generation of the devices with their functions. As it can be noticed from the Table 4.1, Intramed^{TM} has the largest number of keys, 7 in total. However, beside of start and stop button, which should be present in each device, the other keys are reserved for the parameters setup. If we put the parameters setup options within the user menu, then the requirement for common user interface on all devices can be achieved. In this case all six devices should have the following five keys:

1. *start/stop* – controls the beginning and the end of the therapy,
2. *up* – moving up within the menu, or parameter value increase,
3. *down* – moving down within the menu, or parameter value decrease,
4. *enter* – enter the selected menu item, or remember the parameter value,
5. *back* – one level up in the menu, or cancel the parameter value.

The menu is organized as shown in Fig. 4.1. The initial screen in Fig. 4.1 gives the operator the basic information about the device type, notifying that the device is in ”ready” state. The most common task performed on the device is starting of the therapy. Within the designed menu, this is provided with the most recent parameters, which are recorded as *”predefined therapy 1”* option (Fig. 4.1). The therapy can be started from the *ready* state by pressing the *start* key twice (Fig. 4.1). While the therapy is in progress, pressing the *start* button will cause the first parameter to be displayed in ”full-screen” mode, letting the operator to change the value by pressing *up/down* keys. The real-time parameters displayed during the therapy on Vakumed^{TM} are shown in Fig. 4.2a, while the screens for parameter changing are shown in Fig. 4.2b.

From Fig. 4.1 can be noticed that a part of the interface is devoted to the communication parameters. By moving down through the main menu, starting from the initial screen, operator can reach the menu item *”Communication parameters”*, where the network parameters can be set.

Table 4.1: The summary of the control functions on the front panel in the previous generation of the devices

	Eksposan	**Intramed**	**Sonoton**	**Magnemed**	**Vakumed**	**Diaton**
key 1	start / stop	start / stop	start / stop	start / stop	start / stop	start / stop
key 2	modulation type	select function (pm,if,g)	select function (k,i1,i2)	channel selection (1,2)	pulse mode (15,30,60)	select function (g,pg,d)
key 3	select function (sp,e1,e2)	frequency change type	-	-	constant mode	-
key 4	-	upper/lower frequency	-	-	water	polarity (+,-)
key 5	set F current (up/down)	time (0-60 min.)	time (0-19 min.)	time (0-95 min.)	vacuum intensity (0-600 mbar)	time (0-15 min.)
key 6	set G current (up/down)	current (0-60mA)	intensity (0-3W/cm^2)	frequency (0-50Hz)	-	base current (0-5mA)
key 7	-	frequency (1-200Hz)	-	magnetic field (0-10mT)	-	dose current (0-29mA)

5. Data Acquisition and Control Protocol

In order to be able to setup treatment parameters remotely in semi-automatic or automatic manner over computer network and to record the progress of the treatment in the ICSPM, each device is provided with the Ethernet network adapter that is embedded in the chosen PIC microcontroller (Fig. 2.3) [9]. The ICSPM is designed as hub-and-spoke topology, having the control station as a hub, as it is shown in Fig. 5.1. In other words, devices can communicate with the control station only, but not with each other.

Regardless the fact that there is only one device of each kind in the Fig. 5.1, the system is capable of handling any given set of devices. The design and implementation of communication protocol is inspired by a set of standards X73 PoC-MDC [6]. To operate in a coupled manner, two devices follow the next four steps: connection, association, configuration and operation. In the phase of connection, the device queries local network for discovery of the control station. During the phase of association the device registers its ID within the control station and retrieves the network ID [6], [7]. In the phase of configuration the device queries the control station to retrieve physical therapy database. It analyzes the type of therapies and updates its local therapies database. In the operation phase the device sends periodic *hello* packets and can be polled by the control station to start, stop or change therapy parameters.

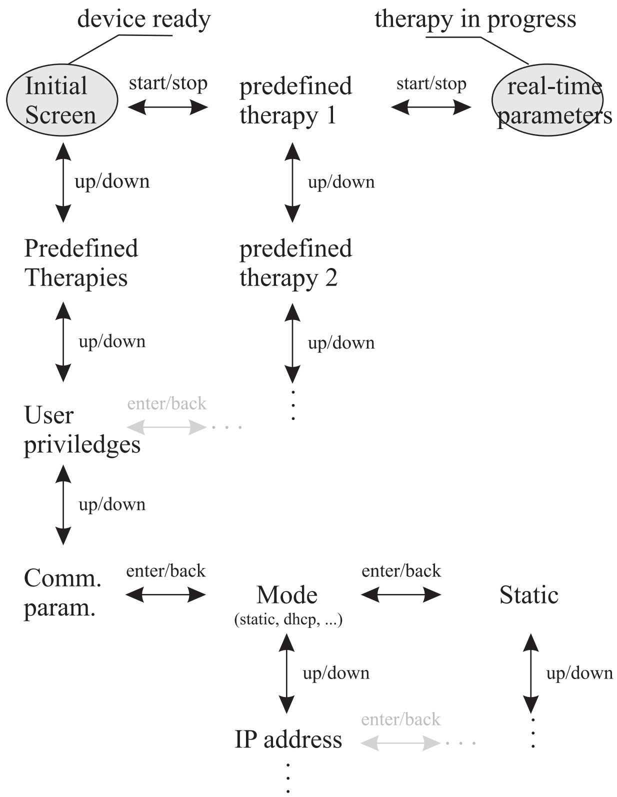

Fig. 4.1: The organization of the user menu on the ICSPM device

Fig. 4.2: Parameters display in real-rime during the therapy

The coding and decoding of messages in X73 is found not to be applicable in straightforward manner for the particular embedded microcontroller, due to complexity [2]. The protocol message coding is simplified to reflect the number and type of physical therapies parameters [9].

The communication protocol between the physical therapy device and the control station is designed to use UDP transport layer protocol with port numbers 161 and 162. As UDP protocol doesn't offer transmission and flow control, the basic sequencing and acknowledgment of messages are provided at the application level.

The message format is shown in Fig. 5.2. There are 18 different message types, which are used in different scenarios for different purposes. Sign "D" in Fig. 5.2

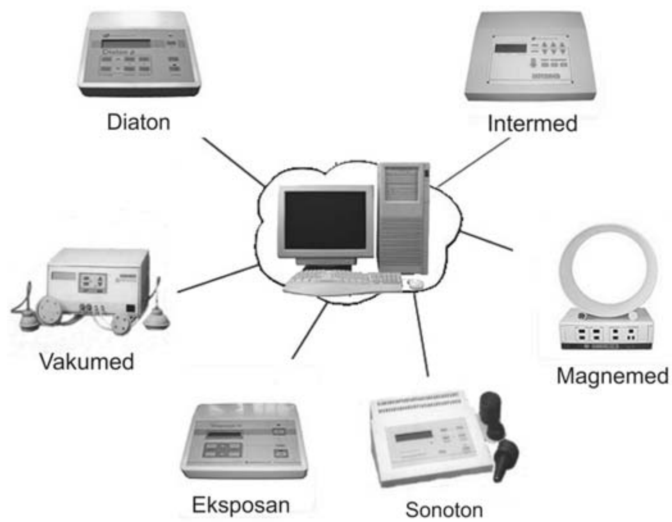

FIG. 5.1: The topology of the ICSPM

stands for field delimiter.

0 2	3	4 8	9	10 N+10	N+11
Code	D	Device ID	D	Message	End

FIG. 5.2: The message format

The following scenarios are identified:

- starting of the therapy with predefined parameters from the control station;
- recording the event if the therapy is started/stopped from the device itself;
- pausing or stopping the therapy from the control station;
- changing the therapy parameters from the control station;
- recording the event if the parameters are changed from the device itself;
- periodic interchange of status information between devices and control station;
- sending of unsolicited messages about starting or stoping of therapies, changing parameters or changing of device states from the device;
- new therapy registering if it doesn't exist in the control station database.

The complete list of message codes and detailed description of the message exchange during each scenario can be found in the technical report [10]. For the sake of illustration, a UML sequence diagram for one of the mentioned scenarios is presented in Fig. 5.3. The scenario illustrated in Fig. 5.3 is the scenario of starting the therapy on a device from the server.

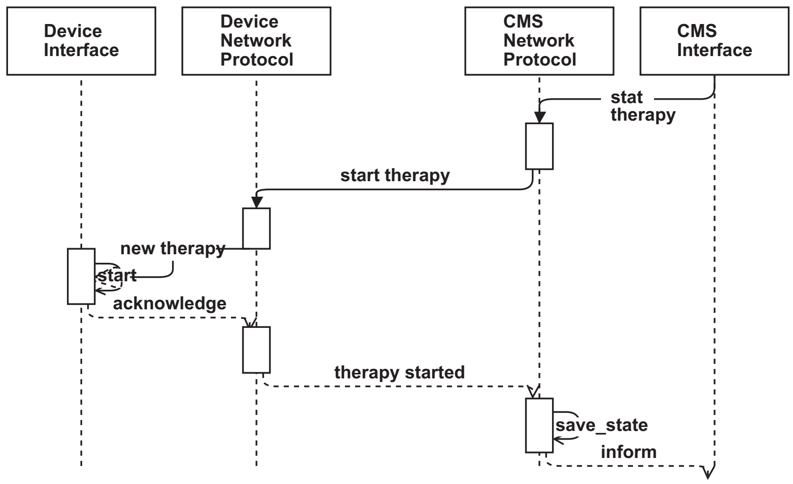

Fig. 5.3: The sequences of messages sent over the network when therapy on a device is started from the control station

After the command is received to start the therapy on the particular device (Fig. 5.3), the user interface on the station notifies the module which implements the protocol on the control station to send a start message to the device (*start_therapy()*, Fig. 5.3). The module that implements the protocol on the device side, gets the message, takes the necessary steps, and confirms the start to the control station. It should be noted that this scenario must precede by the message exchange which connect, and associate, the device to the control station [10].

Beside these similarities, the implemented protocol has less overhead compared with full X73 protocol stack.

6. Control Station Management Console

The part of the management console of the control station is shown in Figs. 6.1 and 6.2. Due to importance of particular parts of the user interface, patient data management, as well as the information about available devices are omitted.

As it is shown in Fig. 3.2, at the beginning of the process the patient needs to be identified. This can be done either by entering medical record ID, or unique ID of the citizen (JMBG field in Fig. 6.1). If the cabinet is equipped with barcode reader, or any other kind of reader, this information can be automatically filled in the form.

In the case of barcode reader it is straightforward, because the only requirement is that corresponding text box has the focus.

Once the patient is identified, and its record is opened, after entering the basic information about the patient the operator on the central control station gets the scheduler screen shown in Fig. 6.1. Due to the user requirements, the interface is in Serbian. The scheduler lets the operator enter the type of the device, the number of the therapies, and preferences for the planer, such as the affinity for morning or afternoon time slots, ability to alternate the affinity every week, and choose the time slots in particular days in week. According to given preferences and availability of devices, the scheduler creates the treatment plan, and presents it to the operator. The operator is provided with drag-and-drop functionality for fine-tuning the plan.

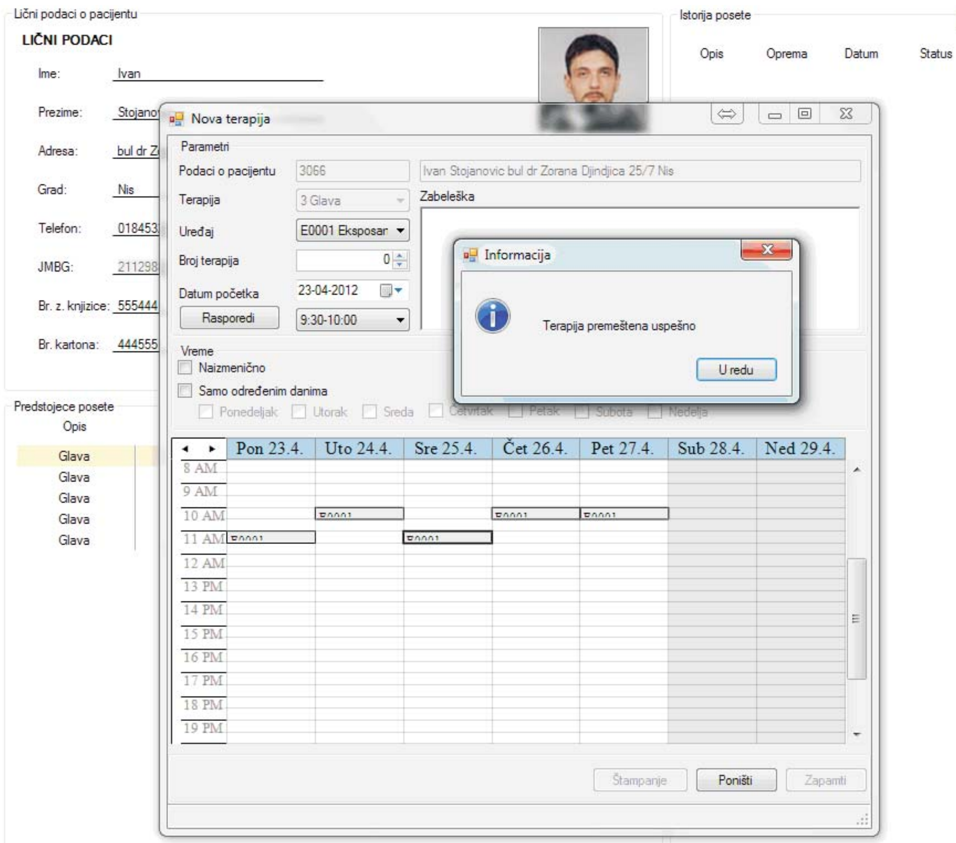

Fig. 6.1: The scheduler

When the treatment plan is created the management console shows the patient's record, which consists of basic info about the patient, the list of future therapies and the therapies history (Fig. 6.2). Only the first row in the list of the future treatment shows the ID of particular device where the treatment parameters will be sent. The medical staff should direct the patient after identification to that particular device (device E0001 in Fig. 6.2). In addition to the mentioned three, the screen is divided in 5 sections in total. In order to be able to reference the sections of the figure, the sections are enumerated by numbers 1 to 5 in Fig. 6.2.

Fig. 6.2: The management console of the control station

The main design goal was to provide all patients data, including the data about scheduled therapies once the record is opened. These data are provided within sections enumerated as 1 to 3 in Fig. 6.2. Section 1 shows the basic information about the patient, while sections 2 and 3 give the information about scheduled treatments and the history of treatments, respectively.

Sections 4 and 5 display the current status of the devices in the ICSPM. The status of the devices on which the therapy is in the progress is shown in section 4, along with the elapsed and estimated time for the treatment. If the device is in ready state, and the treatment isn't running, the device isn't displayed in this section. In addition, section 5 displays the event messages about the devices, such as: new device detected on the network, therapy parameters changed on the device using the interface of the device itself, etc. These messages are visible for the short period of time, and then they disappear from the list of events.

If there are no therapies in progress, and there are no events from the devices, sections 4 and 5 are hidden, and the screen contains sections 1 to 3 only. As it is mentioned earlier, section 2 displays the scheduled treatments for the patient whose record is opened, putting the first coming treatment on the top. The first coming treatment is the only one that has buttons for start and edit, the therapy parameters next to it, on the right side, as it is shown in Fig. 6.2. When the treatment is started, the start button icon switches to stop button, the edit button remains the same, and the progress is shown in the section 4 of the screen.

The third row in the section 2 shows the type of the device (Fig. 6.2). The first coming treatment is the only one where the particular ID of the device is shown, because in this point control station has the information which device is available. This is not the case with the treatments scheduled for some future time. The problem of availability of the devices in particular period of time is addressed in the scheduler part of the interface, but it addresses only the number of available type of the devices, and do not associate the patient to the device until the time for the treatment comes.

Having all relevant information available on the same screen met one of the basic rules of HCI design, and indirectly gave the opportunity to the institution to choose between regular and touch screen while implementing the ICSPM.

7. Implementation Results

The physical therapy devices are upgraded with a microcontroller-based board, using Microchip PIC 18F87J60 with integrated Ethernet controller (Fig. 2.3). The protocol stack is compiled using MikroC compiler within MikroC PRO IDE and runs on MikroC TCP/IP stack in OSA cooperative multitasking real-time operating system (RTOS) for Microchip PIC controllers. The size of the compiled protocol core is 44KB. The corresponding component, as well as the user interface on a control station, is developed in C# with .NET 3.5.

For the sake of illustration, Table 7.1 gives the total number of messages that can be exchanged between a device within ICSPM and control station through the network, and the total number of different events caused by the messages within the control station, as well as within the device itself.

Table 7.1: The number of messages exchanged between the system modules

Message	# of messages
Device protocol → Station protocol	15
Station protocol → Device protocol	19
Station protocol → Station interface	20
Station interface → Station protocol	8
Device protocol → Device interface	15
Device interface → Device protocol	15

Table 7.2 shows the number of messages exchanged for one working day of 10 hours, between 12 physical therapy devices and control station, when the therapies are scheduled on every 30 minutes. Having in mind that the average message size is 80B, and that total quantity of data exchanged per day for the given example is less that 1MB, it can be concluded that the protocol is very efficient both in terms of network throughput and, more importantly, the burden that it causes on the limited-capability microcontroller.

Let us estimate the efficiency of the cabinet in the number of patients per device per day.

Table 7.2: The number of messages exchanged over the network in the typical cabinet

Scenario	# of messages	# of repetitions per day	data sent [KB]
Device registering	5	1	0.4
HELLO messages	2	3600	562.5
Starting of therapy	2	20	3.2
Stopping the therapy	2	20	3.2
Parameters change	2	100	16.0
Synchronization	24	1	1.9

The sequence of actions within the common physical therapy cabinet is the same whether or whether not the cabinet is equipped with the ICSPM: after the identification of the patient the operator obtains the therapy plan, sets the parameters and starts the therapy. The difference in Fig. 3.2 if the cabinet is equipped with ICSPM is in the components that are used to complete these actions , i.e. the scheduler will automatically find the best plan for given parameters, the data would be recorded instantly, and instead of manual setup of the parameters, the setup and the start of the therapy would appear instantly after the identification of the patient.

The table 7.3 shows comparative analysis given in estimated mean time (EMT) in minutes for the actions from Fig. 3.2, in the case when the cabinet isn't equipped with ICSPM, and when it is. If the cabinet is equipped with ICSPM, the identification of the patient in the subsection 2.1 (Fig. 3.2) takes the same time, but the scheduling of the therapies (sec. 2.2) is slightly faster. In the case when the ICSPM is employed, the actions denoted as 2.2 and 2.3 are performed instantly. The action 2.1, the patient identification, can be further speedup using RF ID cards. For the sake of illustration we will not consider the speedup of the action 2.1 (Tab. 7.3).

Section	EMT without ICSPM [min]	EMT with ICSPM [min]	The average number of repetitions per day
1.1	5	5	
1.2	5	2	
Total 1.1-1.2	10	7	2-3 per device
2.1	2	2	
2.2	3	0	
2.3	5	0	
2.4	15	15	
Total 2.1-2.4	25	17	20-25 per device

Table 7.3: Estimated mean time (EMT) in minutes for the actions from Fig. 3.2

Let us estimate the efficiency if the ICSPM is employed. We will assume that the working hours of the cabinet is 12 hours per day. The required time-per-patient (TPP) for the cabinet without ICSPM is 25 minutes (Tab. 7.3). If the therapies are scheduled every 30 minutes, the total number of patients per day per device is 24. According to the EMT given in Tab. 7.3, the TPP for the cabinet with the ICSPM is 17 minutes. If the therapies are scheduled every 25 minutes, which gives even more idle time between two therapies, the total number of patients per day per device is 29. With this estimation we obtained that the efficiency of the cabinet is $29/24 \approx 121\%$, which is approximately 21% better than the cabinet without the ICSPM. Expressed in the number of patients, 5 more patients can be served per device per day in the cabinet with the ICSPM, than in the cabinet without the ICSPM.

Having in mind that each patient has 5 to 10 treatments in total, if more than 20 patients are served per day per device, then 2-3 patients should be registered for the first time per day per device during their first visit (Tab. 7.3). The registration of the patient on the first visit and creating the therapy plan is slightly faster in the case with ICSPM, but the number of the patients is small. Thus, this difference is neglected in the previous estimation of the efficiency.

8. Conclusion

In this paper the development of hardware/software components and network protocol for integrated system of devices for physical medicine, based on the existing products of Elektromedicina company, with key feature that allows the devices to be centrally managed and monitored is presented. The devices are based on existing products of Elektromedicina company, with key additional feature that allows the devices to become a networked modules in the centralized system for physical therapy. This paper addresses the system's architecture, user interfaces both for devices and centralized server console, network protocol for communication between devices and centralized management station, the scheduler, and the therapy procedure within the system. Both local and remote aspects of setting the treatment parameters on the devices, as well as the monitoring of treatment progress on the centralized control station with data acquisition are implemented. The new user interface on devices and the user interface of the control station are presented. The application layer protocol for communication of control station and physical therapy devices is developed. The protocol design is led by the concepts of IEEE ISO/IEEE X73-PoC-MDC series of standards. To deal with limited resources of a microcontroller-based interface, which is attached to each physical therapy device, adopted concepts are simplified accordingly. The proposed protocol provides plug-and-play capability of physical therapy devices through handling of devices discovery and synchronization of therapy databases. The initial implementation proved that the networked physical therapy devices can respond to all requests in a timely manner. It is shown that the efficiency of the integrated system, measured in the time-per-patient and patients-per-day, compared with the efficiency of regular physical therapy cabinet is increased by more than 20%.

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REFERENCES

1. American Physical Therapy Association, *Todays Physical Therapist: A Comprehensive Review of a 21st-Century Health Care Profession*, January, 2011, pp.85-86.
2. I. Martnez et al., *Implementation Experience of a Patient Monitoring Solution based on End-to-End Standards*, 29th International Conference of the IEEE on Engineering in Medicine and Biology Society - EMBS, August 2007, pp. 6425-6428.
3. Hak Jong Lee et al., *Ubiquitous healthcare service using Zigbee and mobile phone for elderly patients*, International Journal of Medical Informatics, Vol.78, No. 3, 2009, pp.193-198.
4. Kris R. Holtzclaw *Router device for centralized management of medical device data*, U.S. Patent, No. US 2007/0255348 A1, 2006.
5. Satoru Miwa, *System for centralized management of medical data*, U.S. Patent, No. 4974607, 1990.
6. Galarraga M, Serrano L, Martnez I, de Toledo P., *Standards for medical device communication: X73 PoC-MDC*. Stud Health Technol Inform. Vol.121, 2006, pp.242-56.
7. Jianchu Yao, Steve Warren, *Applying the ISO/IEEE 11073 Standards to Wearable Home Health Monitoring Systems*, The Journal of Clinical Monitoring and Computing, Vol. 19, No. 6, December 2005, pp. 427-436.
8. T. Su-Lim, B. Tran Nguyen, *Survey and performance evaluation of real-time operating systems (RTOS) for small microcontrollers*, IEEE Micro, Vol. PP, No. 99, 2009.
9. Vladimir Simic, Vladimir Ciric, Teufik Tokic, Ivan Milentijevic, *Communication Protocol Design for Physical Therapy Devices*, 18th Conference YuInfo, Kopaonik, Serbia, 2012, pp. 396-401.
10. Vladimir Ciric, Vladimir Simic, Teufik Tokic, Darko Tasic, Emina Milovanovic, Igor Milovanovic, *Design and Implementation of Network Communication Protocol for Physical Medicine Devices*, Technical report, Faculty of Electronic Engineering, Nis, Serbia, 2012.

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