Data fusion from different protocols and integrating them into a mesh network for personal assistant of technical manager

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Automatic data collection and decision-making processes are crucial in optimizing production processes. One of the main tasks is to significantly reduce the time and cost of making management decisions, and achieve flexible and safe operational management of activities. For this purpose, a personal assistant of the technical manager has been developed, providing timely and up-to-date information, necessary for making an adequate and reasoned decision. The key element in this system is the layer responsible for collecting and transmitting data from executable objects. The lack of connectivity or the obsolescence of the transmitted parameters would be critical for the operation of the whole system. A model of architecture and algorithm implementation, for combining data from different sensor nodes, using different communication protocols, and integrating them into a single mesh network is proposed in this paper. An algorithm has been developed to reduce the communication time between individual elements and the layer for data collection and analysis.

Keywords – personal assistant of technical manager (PATM), protocol mesh architecture, data hub algorithms.

Обединяване на данни от различни протоколи и интегрирането им в пълносвързана мрежа за персонален асистент на технически ръководител. (Боян Медникаров, Йордан Сивков, Чавдар Александров, Мирослав Цветков, Веселин Атанасов, Маринела Петрова) *Автоматизирането на процесите на събиране на данни и вземането на решение е от решаващо значение при оптимизирането на производствените процеси. Една от основните задачи е съществено понижаване на времето и разходите по взимане на управленски решения, както и постигане на гъвкаво и безопасно оперативно управление на дейностите. За целта е разработен персонален асистент на техническия ръководител, осигуряващ навременна и актуална информация нужна за вземането на адекватно и обосновано решение. Ключовият елемент в тази система се явява слоят отговарящ за събиране и предаване на данни от изпълнителните обекти. Липсата на свързаност или неактуалност на предаваните параметри биха били критични за работата на цялата система. Предложен е модел на архитектура и реализация на алгоритъм за обединяване на данните от различни сензорни възли използващи различни комуникационни протоколи и събирането им в единна меш мрежа. Разработен е алгоритъм за понижаване на времето на комуникация между отделните елементи и слоя за събиране и анализ на данни.*

Introduction

The automation of data collection processes to make a decision is critical in the optimization of production processes.

A model of intelligent personal assistant of a technical (operational) manager (PATM) in open space production is investigated as an approach to the robotization and automation of the operational management of complex objects. This is a development of the automated transport activity management system, implemented by Scortel Ltd., and a continuation of the innovative activity of the company in the field of ICT (Information and communications technology) and its application in industry and transport. Developing advanced technology in the field of artificial intelligence is used - the intelligent agents that underpin intelligent personal assistants.

System layers

One of the main tasks is to reduce the time and cost of management solutions significantly, in order to achieve flexible and safe operational management of activities (processes) in the operational environment of an automated system for managing transport activities in open space production.

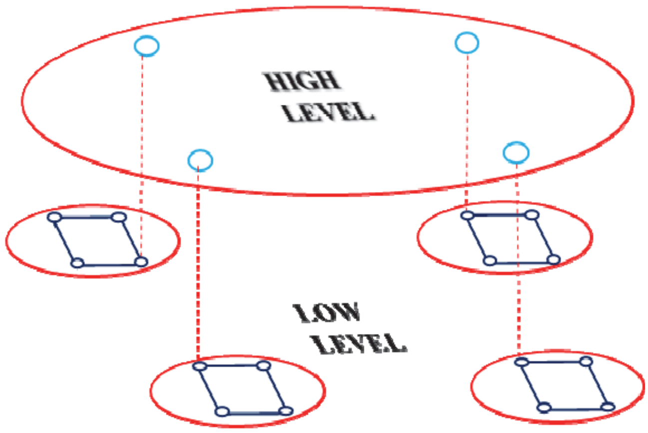

Fig.1. Hierarchical network.

The considered model uses the network topology of hierarchical networks (see fig. 1 and fig. 2) using two main levels: low level – for data collection and transmission (Data Collection and Network Layer) and high level – for archiving and processing of information for the purposes of the Technical Manager and process management at the operational level (Data&Analysis Layer).

In the schematic on fig.2 can be seen a third, presentation level, used to present the data to the technical manager, and to manage the low level.

A detailed description of the architecture and its individual elements is shown on fig. 3. The data collection layer is represented by sensor nodes located on platforms (mobile or fixed), which can be both fishing vessels and heavy machinery, used in construction activities. The information they provide through converters is transmitted to a server for storage and processing.

The last layer is a software resource in service of the technical manager, provided through a computer, tablet or other specialized terminal.

One of the main problems with the implementation of the presented architecture is the reliability of communications between the individual elements and the restoration in case of disruptions. The use of already known solutions is hampered mostly because of the closed ecosystems of producers, as well as the lack of sustainability due to third-party dependencies.

Solving these problems requires the development of appropriate algorithms, software solutions, and hardware implementations based on microcontrollers. One of the most used concepts in the implementation of such systems is the Internet of Things (IoT), which has a large number of open architecture samples [1]-[3], as well as the opportunity for complete customization.

Mesh architecture

The Network Mesh is a basic technique used in the Internet of Things concept. Covering completely the idea of a permanent and full connectivity, this architecture allows a stable and highly operational system [4], [6]. The last feature is extremely important in the implementation of industrial applications and the algorithms, critical to the lack of up-to-date data

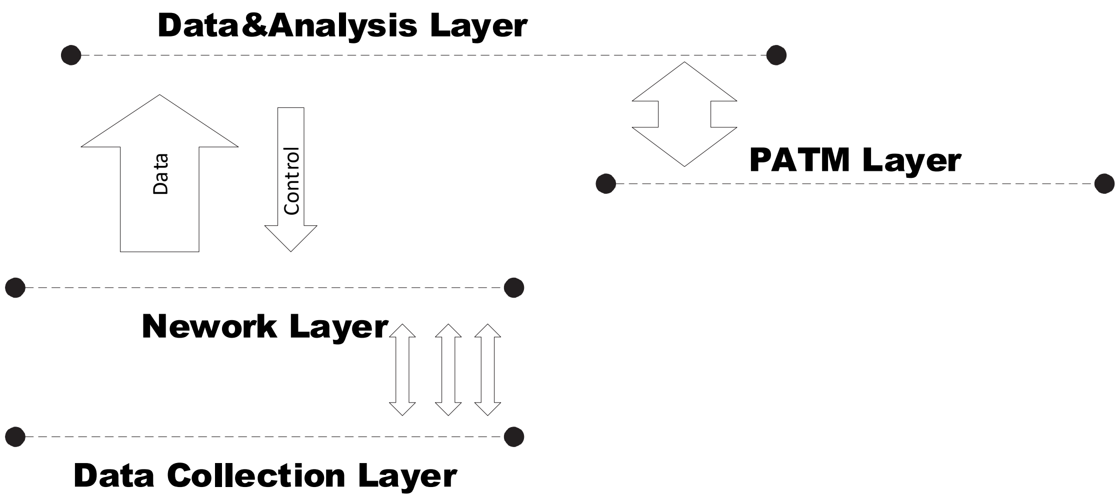

Fig.2. Layers in complete system.

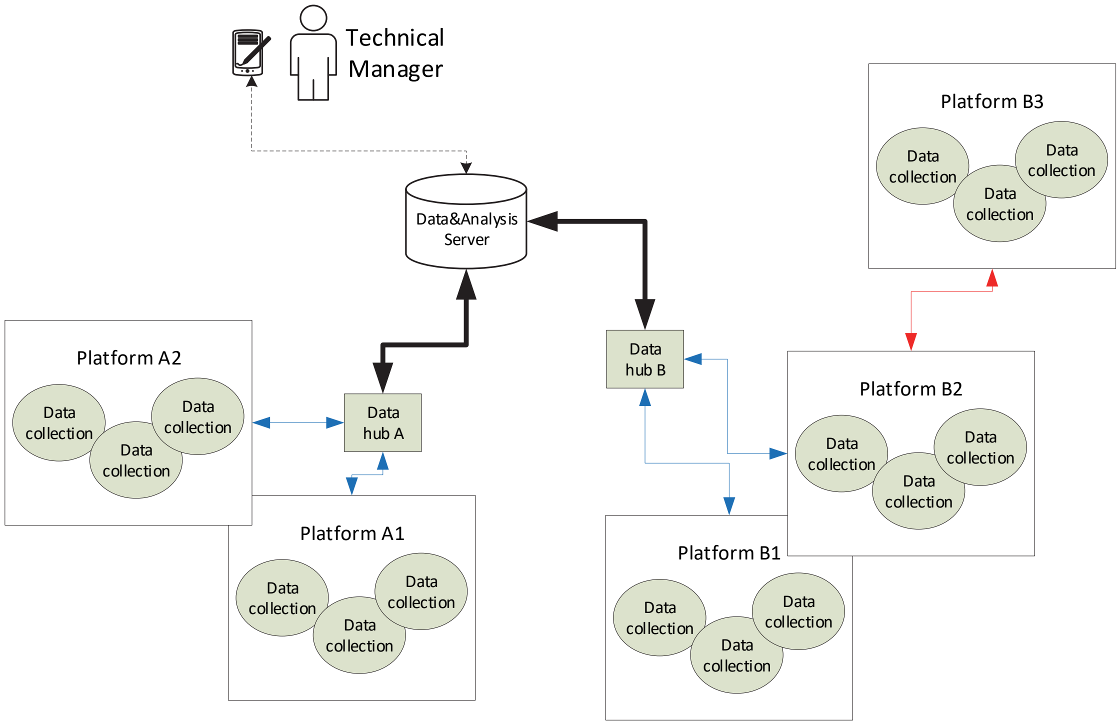

Fig.3. Low level system architecture.

and can lead to the wrong or suboptimal decision, which in turn will lead to the loss of both financial and time resource [7] – [9].

Using many-to-many connections would help in the following aspects:

- Transmission of data from remote nodes.
- Increasing the resilience of connectivity in the system.
- Reducing consumption due to the potential for more items to use less energy for their work.
- Including option for usage of batteries for power supplies to maximize energy independence.
- Achieving more dynamics in building platforms.

Coordinating a large number of mechanized units with specific parameters and states requires flexibility in implementing a data collection system for its characteristics. In many cases, the system is not static, but a living and evolving structure that is constantly upgrading at different times in its life cycle. This development is sometimes confronted with the lack of previously used nodes or the availability of new, more functional patterns than the previous ones.

This requires the whole system or at least a part of the interfaces to remain open for future compatibility [3], [6], [10].

A cross-protocol mesh architecture is needed to build nodes that transfer data between different protocols in order to take advantage of each individual implementation, as well as to avoid the disadvantages of others. The use of different protocols also helps to increase the invariance of the realization [6], [8].

When using Bluetooth (BT) sensor nodes, for example, there is a low level of consumption and minimal implementation, but a relatively short data transmission range. On the other hand, ZigBee or LoRaWan provide significantly longer range, but increased consumption over the previously discussed protocol [1], [2], [7].

In order to be able to merge different protocols, it is necessary to build specialized nodes (see fig. 4) based on microcontrollers, such as the ESP32, Arduino, Raspberry Pi [9], STM Nucleo platforms or others. They are upgraded with the necessary interfaces, as well as with an appropriate software [5].

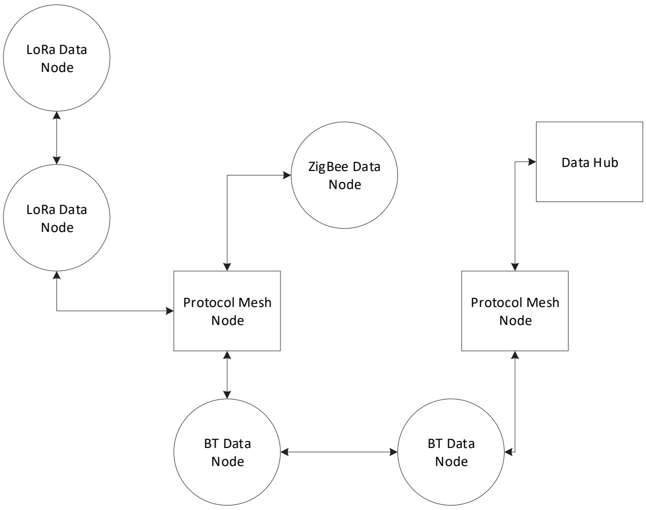

Fig.4. Protocol mesh concept.

The following requirements must be satisfied when implementing a protocol mesh node:

- provision of a higher capacity power source due to the operation of multiple interfaces;
- usage of a non-blocking software model;
- development of a connectivity table.

The connectivity table must include the level of connectivity to the different Data Hubs of the neighboring nodes, in order to reduce the time of data transmission to the senior level.

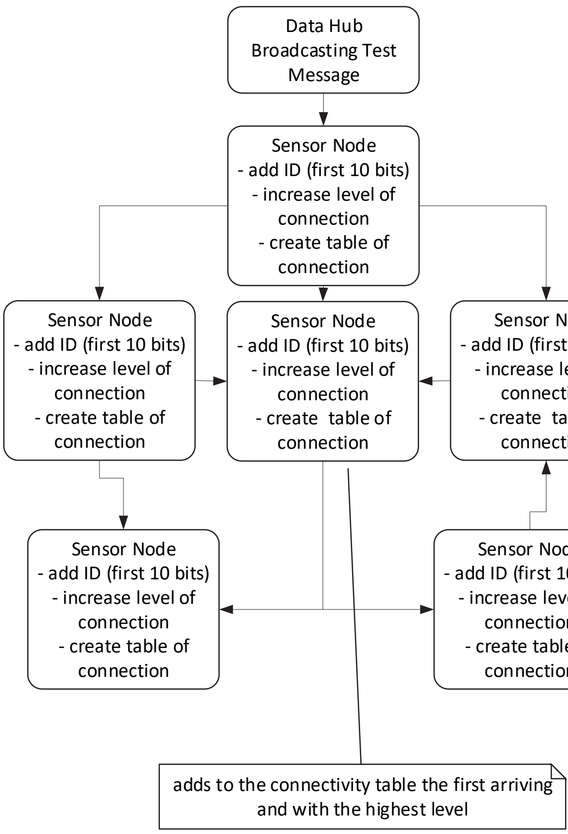

Fig.5. Connectivity table flowchart.

The table contains the IDs of all the connected nodes as well as their level relative to the Data Hub. Level determination is done by the hub emitting a test signal with its identification number and value zero, and each subsequent node adds its identification number to that of the hub and increases the value with one. This way, each node knows which level it is after the hub, and in which direction it should redirect data to the mesh.

0000000001	000001
10 bits Node ID	6 bits DH ID

15b 6 5 0b

Fig.6. Data hub and sensor node ID message.

In the received message, each node replaces the first 10 bits of the identification number with its own and increments the counter, and then transmits the message to each associated one, except the node from which the message was received.

Upon receiving a message that has a lower level (respectively greater number) than that of the given node, the message is ignored and does not spread.

In case of loss of connection between Data Hub and server, a protocol is activated for reconfiguration of the nodes. The protocol is also activated when Data Hub connectivity changes.

After completing the connectivity table, each of the sensor nodes can transmit data without causing network overflow, which in turn helps to reduce data transmission time and increase system resilience.

The conventional mesh protocols provided in the different standards are not used due to the interconnectivity building. The latter requires additional software development, but in the long run ensures system compatibility and scalability.

The 16-bit ID header binds up to 1000 sensor nodes and 63 Data Hubs. If needed, a larger number can be expanded up to 32 bits.

Network layer

The communication layer is implemented by a Data Hub, which is a device, connecting sensor nodes to a server that aggregates the information and is responsible for processing it. As a connecting element, it is the key in the construction of the model and its lack or incapacity causes the entire system to shut down. To ensure responsiveness, each element of the critical infrastructure must be duplicated at the physical, logical and functional levels.

Computer network terminology is used in choosing the name of this element, but unlike the traditional network hub, the proposed element will also convert the physical and logical level of data between different protocols, and will create a pre-developed protocol message as well.

The Data Hub has the following main tasks:

- Communication with sensor nodes - depending on the configuration, the device integrates and prepares the transmission data in a created protocol and provides signals to draw up tables of connectivity between nodes.
- Server connection - A connection must be provided to a server on an Ethernet network, generally the Internet, or only by using its environment, and for cybersecurity, by using a VPN tunnel.
- Data analysis to reduce traffic and to optimize the load on both networks - Traffic optimization is a major problem for modern communication systems. Data analysis is also performed on the basis of the information transmitted and its content related to its users.
- Evaluation of communication channels and implementation of a communication stability algorithm.
- Broadcast message for forming mesh connectivity tables of different protocols.

For the technical implementation of the device, a microcomputer is used, capable of satisfying requirements as follows:

- Enough processing power - analyzing, converting and sending large amounts of data requires adequate computation performance.
- Small in size - integrating new elements into existing architectures and locations requires minimal change footprint.
- Low consumption - as with the above requirement, low consumption is a combination of a minimal footprint as well as reducing the extra heat released in the environment.
- Low cost - the economic factor, although not leading, is one of the important factors in building any system. Low cost should not affect functionality, but should be achieved on the basis of a unified design with large applications, resulting in reduced production costs due to mass production.
- Unified design - the use of a widespread device that has been tested and validated by a large number of users, will allow cost reduction, on the one hand, and the use of a large number of additional platforms and modules developed, as well as widespread support from software developers and a community of high-level enthusiasts of documentation, on the other hand.
- Modular design - enable to include additional functionality such as sensors and / or interfaces. The construction of this modular design requires the pre-construction of a modular structure of the work model and the use of a suitable software package.

An algorithm for evaluation of communication channels and their resilience

The flowchart, shown on fig. 7 is based on measuring the time delay in the individual channels and estimating, based on predefined criteria, the cost of the transmitted data. Each of the described parameters is entered in a table containing the weighting factors depending on the priority of the message.

Priority is determined both by a predefined factors and as an estimation of the rate of change of a parameter over a certain period of time, or passing a threshold. For example, if there is a platform that transfers resources between objects, or from a warehouse to an object, it would change priorities only if facing a disruption or a limit, hindering the delivery time. For the rest of the time, the transmission of this information will be done with minimal resource consumption.

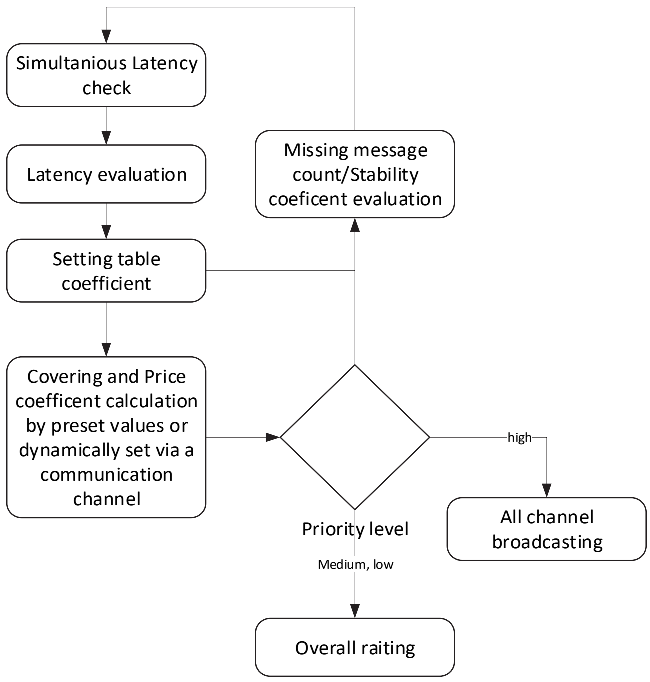

Fig.7. Flowchart of the algorithm for evaluating communication channels and their resilience.

Table 1 shows an example for the evaluation of three channels, where factors are defined for each of the selected parameters. All values are based on previous studies and the criteria laid down in them, as well as their needs [3].

Table 1

Selected parameters for evaluation of communication channels

	WiFi	GSM	Satellite
Latency	3	2	1
Stability	2	2	4
Price	10	5	1
Covering	4	5	6
Data rate	3	2	1
Overall:	22	16	13

The aim is to obtain a comparative quantitative measure of the evaluation of communication channels and their resilience. Each of the parameters can have different maximum values, and the complex result is obtained by summing each of them.

The latency and stability parameters are measurable in a loop, while the other parameters are dynamically set by the higher-level information system. The recent is done based on location analysis, surveys and statistical analysis.

The resulting score is indicative and depends on an user or algorithm-based optimization, such as time, volume of transmitted data, and stability of the provided connection.

Conclusion

The analysis made in this paper defines the architecture of a system providing a personal assistant to the technical manager. The main advantage of an automated system and the ability to collect data from a large amount of sensors at points of interest, such as the various platforms in open production are presented.

Building a mesh network of nodes, using different interfaces, is an unconventional approach that provides future compatibility and scalability.

The use of the flowchart proposed in this research helps to optimize the use of different channels in transmitting data from one level to another with minimum delay. This leads to an increase in the efficiency of the management, and hence the decisions taken. The development of an information system also provides an opportunity for further subsequent analysis and identification of weaknesses, or places with needs of optimization.

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