Improvement of transportation process management effectiveness: assessment and analysis of network topologies

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Abstract. The article focuses on such a concept as "network topology", which plays an important role in increasing the efficiency of managing the transportation process on the railway. The authors carry out detailed analysis of such network topologies as star, ring, bus, tree and others, and also explore their potential for improvement of the efficiency of railway transportation management. The work examines the advantages and disadvantages of each topology, and also evaluates their capabilities for optimizing the transportation process. Evaluation and comparative analysis of varieties of different network topologies is a relevant and interesting area of research. The results of the study confirm that the choice of a specific network topology can significantly affect the efficiency of transportation process management. Some network topologies can significantly reduce shipping costs and improve the overall delivery record, while other topologies can have the opposite effect.

1 Introduction

Improving the efficiency of transportation process management is a key factor for any logistics organization involved in the transportation and delivery of goods or services. Thoughtful management of the transportation process is essential to ensure operational efficiency, satisfy passenger needs and increase the competitiveness of the transport enterprise.

Assessment and analysis of various network topologies are integral elements in improving the efficiency of transportation process management. Network topology allows you to assess current problems and shortcomings in the transportation system, as well as identify opportunities for improvement [1].

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One of the key factors influencing the efficiency of transportation process management is the network topology, which determines the physical structure and organization of network elements. Currently, there are many different network topologies, such as star, bus, ring, fully connected network, partially connected network, etc.

2 Problem statement

The purpose of the study is to conduct an assessment and comparative analysis of various network topologies with the ability to determine the most effective of them to improve the transportation process management.

The performance of network topologies is assessed based on various metrics such as throughput, delay, fault tolerance, scalability and power consumption. All these factors, in their turn, play an important role in determining the efficiency of the network in context of transportation process management. For example, high throughput allows to process a large amount of data, and low delay guarantees the fast information transfer [2].

3 Research questions

The role of network topology in the transportation process is to ensure communication between the various subsystems and devices that is necessary for the efficient functioning of the railway system. Network topology provides the infrastructure for data, voice and control communications between various nodes and devices in a railway system.

Network topology allows to optimize transportation processes, providing:

1. connection of various sensors and devices installed on railway tracks to monitor and control the condition of the infrastructure, such as train position detection systems, speed measurements or safety sensors;
2. exchange of information between trains and the dispatch center, which allows to carry out the quick control of the movement of trains, plan routes, control the speed of movement and prevent possible accidents;
3. the ability to transfer cargo data, payment and financial information to manage logistics processes, including cargo tracking and payment for services;
4. access to information about train schedules and timetables to passengers, which helps to ensure the passenger turnover, plan the routes and train schedules.

Thus, network topology plays a key role in data processing and communication between various devices in the railway system, which contributes to efficient and safe railway transport.

4 Materials and methods

A comparative analysis of various network topologies allows us to highlight their advantages and disadvantages. Some topologies may provide better throughput but low fault tolerance, while others may be highly scalable but have limited throughput. Comparative analysis allows to select the optimal network topology, taking into account the specific requirements for managing the transportation process [3].

Each topology has its own advantages and disadvantages, and choosing the most effective one depends on the context and specific cases of use.

 https://doi.org/10.1051/e3sconf/202452505003

5 Results

Connecting devices on a network using a bus topology is a simple and affordable way (Figure 1). In such a network, all devices are connected to the same cable, and messages sent from one device are received by all devices on the network. However, only the addressee processes this information [4].

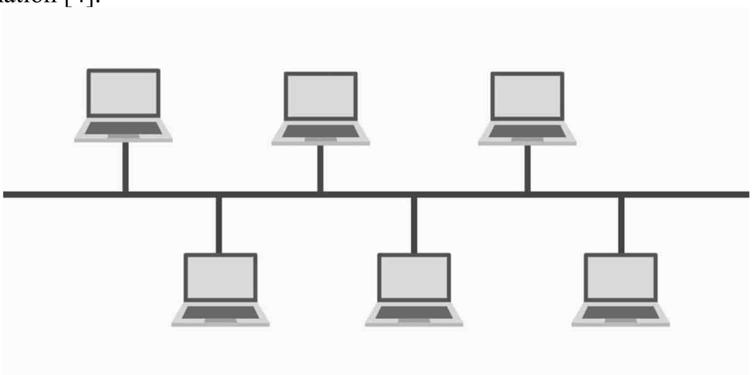

Fig. 1. The "Bus" topology.

However, this topology has disadvantages. If the cable breaks, the entire system stops functioning. Also, fault detection in a bus network can be difficult.

Additional technologies and techniques can be used to improve network reliability and facilitate fault detection. For example, the redundant cables can be installed or devices that can independently redirect data along an alternative path if the main cable breaks can be used. Also, network monitoring and diagnostics using specialized programs and equipment will allow to carry out quick detection and elimination of possible faults.

The ring topology provides high fault tolerance since every point in the network is an "active" device (Figure 2). If one node fails, information is able to bypass the damaged area, choosing alternative paths. However, if any of the nodes fails, the transmission of information in the ring is disrupted, which leads to a breakdown of the entire system [5].

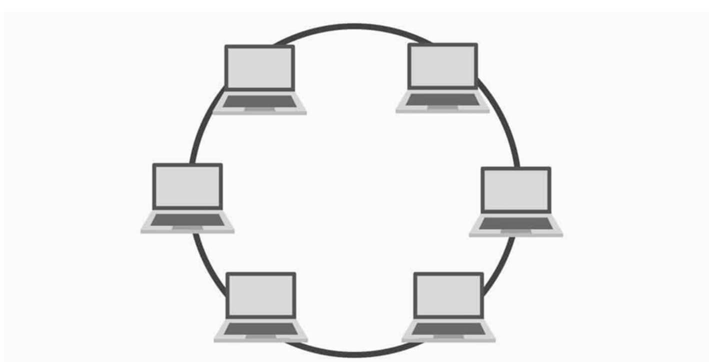

Fig. 2. The «Ring» topology.

This topology is often used in networks where high reliability of data transmission is required, for example, in dispatch and control systems. However, due to the high degree of difficulty in finding and correcting errors, it may not be practical for some other networks. If a problem occurs in a ring topology, each device must be thoroughly examined and tested to identify and fix the problem.

Using the “Star” topology (Figure 3) greatly simplifies the process of network operation troubleshooting. With such a connection, where all workstations are connected to a central node, the failure of one station will not lead to complete system inoperability. However, if the central node fails, the entire network will cease to function.

The Star topology also has high performance, which makes it particularly attractive. It provides efficient distribution of data across the network and is easily scalable in case of necessity of adding the new devices. In addition, this topology provides additional data protection and increased security due to the separate connection of each workstation to the central node [5].

However, it shall be taken into account that while using a “Star” topology, there may be a single point of failure - a central node. If this node fails, the entire network will have to be stopped and its functionality restored. Therefore, it is recommended to have a backup central node or implement a mechanism for automatic switch to another node in case of failure of the main one [6].

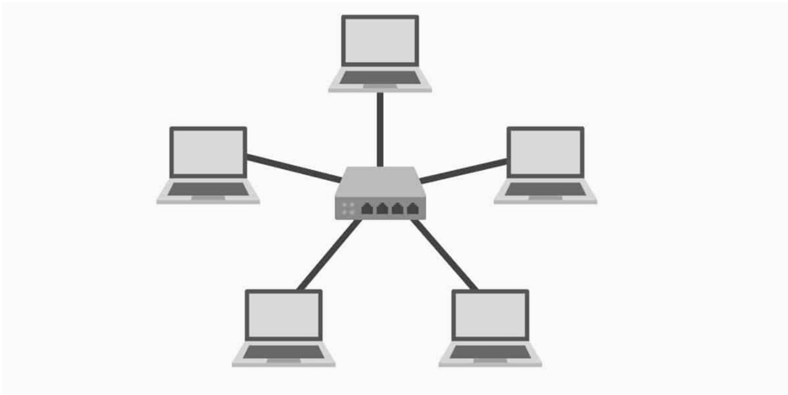

Fig. 3. The «Star» topology.

A fully connected network is a type of network where each node (or data node) is directly connected to every other node in the network. This means that each pair of nodes has a direct connection to each other (Figure 4).

In general, fully connected networks provide maximum throughput, reliability, and minimum delay for data transmission. However, they have a high cost and require additional resources for implementation and maintenance [7].

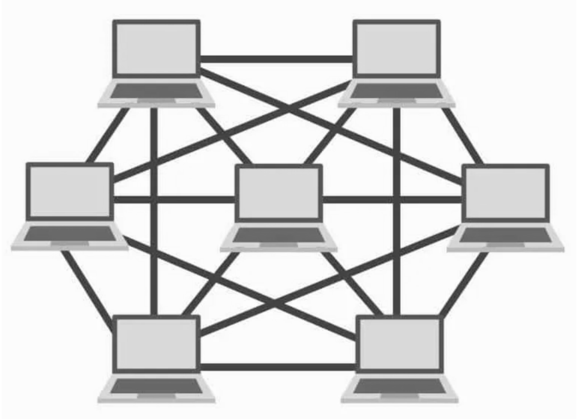

Fig. 4. Fully connected network topology.

A semi-connected network (also known as a tree or hierarchical topology) is a type of computer network where devices are connected in a hierarchical structure or tree topology (Figure 5).

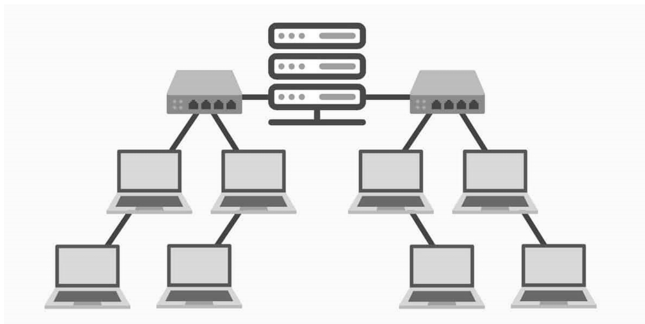

Fig. 5. The «Tree» topology.

6 Findings

Features of existing network topologies are presented in Table 1. The choice of a specific topology depends on the needs and requirements of a particular network.

Table 1. Features of existing network topologies.

Network topology	Advantages	Disadvantages
Ring topology	high throughput, each node has an equal right to transmit data	single point of failure (if one node fails, the network can be disrupted), no possibility of connecting new nodes without breaking the chain
Bus topology	simple and low-cost installation, throughput scales with the addition of new nodes	single point of failure (if the bus fails, the network stops), limited throughput (the bus takes time to transfer data)
Star topology	ease of installation and management, high fault tolerance (if one node fails, the work of the others is not interrupted), scalability and the possibility of centralized control	single point of failure (if the central node fails, the network stops functioning), limited throughput (all data is transmitted through the central node)
Fully Connected Network	high throughput, high fault tolerance (if one node fails, other nodes can transmit data directly)	complex installation and management, high cost, large number of connections and cables
Semi-connected network (also known as tree or hierarchical topology)	Reduced number of connections and cables, simplified installation and management	limited bandwidth between some nodes, possibility of reduced fault tolerance in case of failure of important nodes

According to the analysis presented in Table 1, a star topology can be effective in networks where centralized management and control is required, and failures of individual nodes shall not lead to system downtime. A bus topology can be effective in cases where cost and installation are key factors, but throughput is not a critical consideration. A ring topology can provide high throughput and nods equality fairness, but may be less fault tolerant.

7 Discussion

Fully connected networks provide high throughput and fault tolerance, but they can be expensive and difficult to manage. Semi-connectivity networks may be easier to install and manage, but may have limited capacity and fault tolerance.

Also it shall be noted that each topology may be optimal for a specific type of network or application, as they may have different throughput, delay, and fault tolerance requirements.

Therefore, to determine the most effective network topology, it is recommended to consider the specific needs of an enterprise network and conduct a thorough comparative study of various topology options.

In conclusion, evaluation and comparative analysis of the effectiveness of network topologies is an important step in the selection and optimization of network infrastructure to improve the efficiency of transportation process management. Use of an optimal network topology allows to achieve a reduction in cargo delivery time, improve the quality of customer service and reduce logistics costs. However, it is necessary to take into account various factors, such as requirements for throughput, fault tolerance, scalability and energy consumption, while choosing the optimal network topology and its further optimization for specific conditions of transport process management.

8 Conclusion

Thus, assessment and analysis of network topologies are important tools for improving the efficiency of transportation process management. These include logistics aspects, technological innovations, routing algorithms and system monitoring and control. These factors work together to improve organizational performance, meet customer needs, and increase competitiveness.

In conclusion, the study represents an important contribution to the field of transportation process management. The study confirms that choosing a specific network topology can significantly improve management efficiency and recommends that managers consider these factors while developing transportation management strategies.

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