IMPLEMENTING A GIS APPLICATION FOR NETWORK MANAGEMENT[1]

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Abstract: *The paper proposes a network management system architecture based on a geographical information system that allows accurate description and inventorying of the infrastructure. The system contains several models that emulate real life operational networks based on fiber optics, copper and WiFi technologies. The architecture is implemented in a network management systems application and a number of interesting performance and design problems encountered during the implementation are presented along with their solutions.*

Key words: *GIS; network management system; vector/raster model; rendering performance*

1. Introduction

The evolution of the Internet in recent years has fundamentally changed the way people interact and communicate. This growth of the Internet has led to chaotic development of the infrastructure that supports it.

The development did not take account of hardware used, the interconnection media, software employed, the size of networks that are interconnected or any structured expansion plan. Most extensions were made incrementally, within the limits of the available budgets.

Difficulties arose concerning network design and description, infrastructure expansion and troubleshooting failures. Areas where the focus is on real-time data transfer (medicine, banking, police, army) are seriously affected by lack of network reliability.

Another result of the expansion of the network infrastructure is the increase in the spatial dimensions that can complicate the troubleshooting procedures done in the field by technicians if the location of equipments is not accurately noted. The best way for modeling the geographical dimension of networks is to use a geographical information system (GIS).

2. GIS system definition and concepts

A GIS integrates hardware elements, software and data for capturing, managing, analyzing, and displaying geographically related information. This system allows viewing, understanding and querying data in multiple ways that reveal relationships and patterns in the form of maps, reports or charts.

A GIS helps with answers to questions and solving problems by looking at existing data in an intuitive and easily distributed way.

A GIS can be seen in three different ways: in terms of a database (database view), the map (map view) and model (model view). In Database View the GIS is seen as a structured database that describes the world in geographical terms. In View map the GIS is seen as a set of intelligent maps and sketches which characterized relations over the Earth. In Model View the GIS system is seen as a set of tools for information transforming for obtaining new derived datasets from existing data sets. These tools extract information from existing data, apply analytic functions, and write results into new derived datasets [9][4].

Data representation in a GIS system can be done either in Raster or Vector modes.

Raster mode is essentially any type of digital image represented as an array of pixels. The pixel is the smallest unit of an image. A combination of these pixels will create an image. This representation consists of rows and columns of cells, each cell with one stored value. Raster data can be images (raster image) with each pixel containing a value, usually a color. Additional values recorded for each cell may be a discrete, defined by the user with relevant GIS system, a continuous value, such as temperature, or a null value if no data available. A raster cell that stores only one value can be extended by using raster bands to represent RGB colors (red, green, blue), or an extended attribute table with one row for each single cell unique value. Resolution in raster mode is pixel size in physical units (e.g. distance). Raster data are stored in various formats, from standard file structure of TIF, JPEG, etc., and directly in binary data fields (BLOB) of common databases.

Vector mode is used especially in GIS systems where geographical features are often expressed as vectors, by considering the elements as geometric forms. Various geographical elements are expressed by different types of geometry forms:

- Points - zero-dimensional points are used for geographical elements that can be best expressed by a single point of reference, in other words, simple location. There is no possibility to make any measurements in this case.
- Lines - The lines are used for one-dimensional linear elements such as rivers, roads, topographic lines, and so on. Lines also allow measurement of the distance.
- Polygons - Polygons are two-dimensional elements that are used to represent a geographical area on the surface of the Earth. Polygon features make it possible to measure the perimeter and area.

In order for the GIS to be useful, they must work properly and provide the requested information in a timely manner. The common problems of such systems are scalability and speed of processing user requests. When the system operates with more elements, the scalability problem becomes more pregnant. Problems in repeated rendering of large number of elements appear (e.g. moving the map in a specific direction) when finding a particular item, when querying the system for the position of an element, inserting or deleting an item, and so on [10].

GIS systems used for network modeling

The application integrates a GIS engine based on vector graphics. This means that the application stores all its information in the form of vector primitives: points, lines and polygons. This enables the GIS rendering system to manipulate the information as a vector image.

The geographical component of the data describing the network is divided into two major layers. Each of the layers is later subdivided into several sub layers.

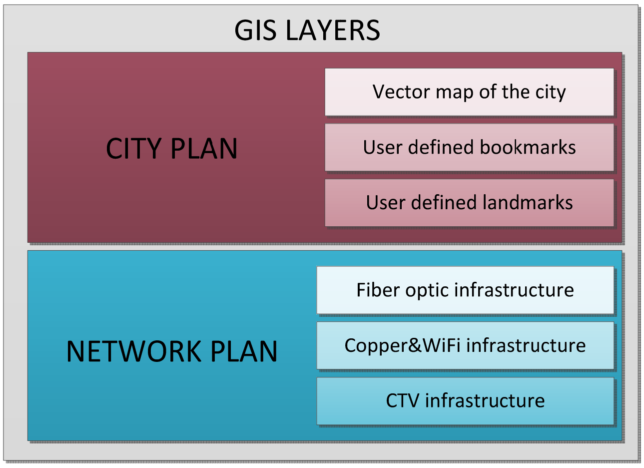

Figure 1. GIS Layers

3. The City Plan

The first major layer is the City Plan that contains information about the terrain topology on which the network operates. The City Plan includes sub layers that describe streets, buildings, duct systems, user defined landmarks. The user defined landmarks are geographic location markers that hold a particular importance for user.

Because a plan of a city contains large amounts of information that is not directly important and is rarely updated, the layer is stored primarily in a vector graphics image format file that is downloaded and stored on the user computer. This is done in order to minimize the resources usage on the database servers because having the city plan stored locally prevents the transfer of redundant information over the network (considering that the city plan is rarely updated) and also saves the server from running exhaustive spatial queries.

The file format used for storing the vector image of the city is Enhanced Metafile - EMF which is a file format type developed by Microsoft intended to be a portable file format between applications. EMF allows the storage and manipulation of both vector graphics and raster graphics in the same file and this in turn enables the creation on mixed maps containing both vector images (where the map vectorization was possible) and also raster image regions (such as satellite images).

There are also downsides to the fact that the vector map is saved locally, being that EMF is a file storage format that offers no spatial indexing or other type of indexing on top of a space filling algorithm (almost all file formats do not have this feature). The lack of any indexing method affects the application's performance. Rendering a rectangle region from vector map with no index can take around two seconds for a 66MB map containing over two million objects.

A quick analysis of the type of queries that need to be run by the GIS engine will show that they involve in most cases the retrieval of a rectangle-shaped region. The height and width of the region are almost all the time proportional to the application window size and to the zoom level selected by the user.

In order to improve the performance of the GIS map rendering subsystem, several practical improvements can be made: splitting the map into sectors and raster caching some of the queries.

There are two feasible approaches when working with large vector images containing large maps:

- **Method 1 -** Raster caching important zoom levels and splitting the image in sectors. The storage is done in raster format indexed on 2D coordinates. Every time a region part of a cached zoom level is requested it is identified and retrieved very fast. Each time the query requests a region that is not cached the system uses the vector map to generate it.
- **Method 2 -** Splitting the actual image into sectors and storing them indexed on 2D coordinates. When a region is requested the sectors that contain parts of it are queried individually and the result is formulated.

In order to evaluate the performance of the methods mentioned above several testing scenarios were developed and ran:

- **Scenario 1** - Map of Bucharest in EMF version, raster caching important zoom levels **(Method 1)**, random regions from the map are requested corresponding to different levels of zoom (random walk on the map).
- **Scenario 2 -** Map of Bucharest in EMF version, vector splitting of the map **(Method 2)**, random regions from the map are requested corresponding to different levels of zoom (random walk on the map).
- **Scenario 3 -** Map of Bucharest in EMF version, raster caching important zoom levels **(Method 1)**, test case containing access queries for regions corresponding to actual real life network.
- **Scenario 4 -** Map of Bucharest in EMF version, vector splitting of the map **(Method 2)**, test case containing access queries for regions corresponding to actual real life network.

The first step in implementing the performance evaluation is to define the needed key performance indicators. These indicators reflect several important aspects like resource consumption and user experience. The main resources used are hard-disk space required to store the map, RAM size needed to store all the data, processor time. Because the user interface is the same in all scenarios and all of them were tested automatically using specific test cases, it is impossible to quantify the user experience. That is why we decided to use as an indicator for user experience the responsiveness of the GIS when changing location, measured as the time between issuing a go-to a location command (jump / zoom / pan) and the time the application fully completes this command.

$$P = Hdd * C_1 + Ram * C_2 + Cpu * C_3 + 2^{T * C_4 - 1} * C_5$$

P - Performance loss indicator

Hdd - Hard drive space required to store the vector map including raster caches measured in megabytes (MB)

C_1 - Transformation constant of performance loss / MB of hard drive space used

Ram - Medium amount of random access memory used by the application during the process

C_2 -Transformation constant of performance loss / MB of RAM used

Cpu - Processor time used by the application for the entire the test case

C_3 -Transformation constant of performance loss / time in second of processor used

T - Average time in second spent in query

C_4 -Transformation constant of performance loss / average time in second of a location query

C_5 -Transformation constant of performance loss / average time in second of a location query exponential effect

The performance loss is a score based indicator that is designed to allow the comparison of the methods presented. A higher score indicates a higher loss of performance. All the resource consumption components are linearly weighted with the use of several constants. The user experience measured as application response time has an exponential effect on the performance loss indicator. By analyzing the behavior of several users we notice that they tend to get annoyed if the application takes more than one second to process a location query, being perceived as application sluggishness. The influence of the T - Average time indicator becomes exponentially more noticeable as queries take longer than one second. The constants C_1.. C_5 have values proportional to the cost of the specific resource on the market: $C_1 = 10$, $C_2 = 100$, $C_3 = 100$, $C_4 = 1$, $C_5 = 1000$.

Scenario 1 and Scenario 3

Several sectors of the city in 2000 pixel by 2000 pixel format stored as jpeg files corresponding to different levels of zoom have been pre rendered from the original vector map. There two test cases one containing ten levels of zoom stored on 476 MB and the second one contains seventeen levels of zoom stored on a 1673 MB. The space required to store the map for one zoom level depends on the surface of the city map. The surface of the city is proportional to the second power of zoom level. This means that the space required increases exponentially.

Table 1. Scenario 1 and 3 results

Scenario 1	Hdd	Ram	Cpu	T	P
Case 1	476 MB	100 MB	10 sec	0.5 sec	16467.11
Case 2	1673 MB	100 MB	10 sec	0.2 sec	28304.35
Scenario 3	Hdd	Ram	Cpu	T	P
Case 3	476 MB	100 MB	15 sec	0.9 sec	17193.03
Case 4	1673 MB	100 MB	13 sec	0.5 sec	28737.11

The main differences between Case 1 and Case 2 are related to the hard disk space and average time needed solve a query. Case 2 has more levels of zoom cached and is able to render faster all the queries that are not covered by the cache used in Case 1.

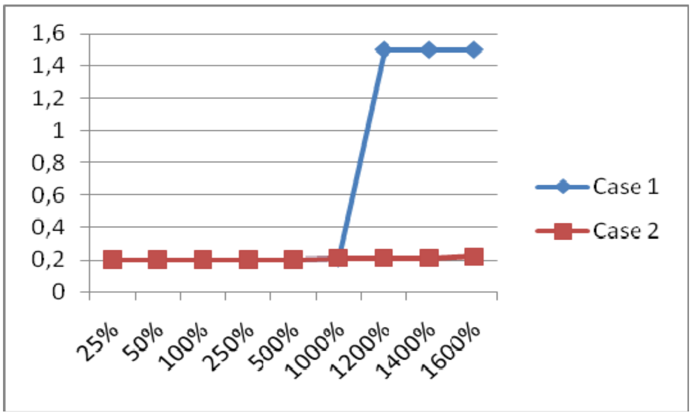

Figure 1. Average time in seconds spent in query for different zoom levels for Scenario 1

The difference between Case 3-4 and Case 1-2 can be explained by the fact that in real life users work on a small area of the map at zoom levels larger than 800% that allow them to see details about the buildings. The random walk uses a normal distribution that evenly distributes the queries on all zoom levels.

Scenario 2 and Scenario 4

The original vector map is split in several rectangular regions stored in vector format EMF file. The original vector map is no longer needed, unlike Scenario 1, as all the data is contained in the split regions.

Table 2. Scenario 2 and 4 results

Scenario 2	*Hdd*	*Ram*	*Cpu*	*T*	*P*
Case 1	50 MB	100 MB	20 sec	0.7 sec	13370.55
Scenario 4	*Hdd*	*Ram*	*Cpu*	*T*	*P*
Case 2	50 MB	100 MB	20 sec	0.7 sec	13370.55

Because in Method 2 (Scenario 2 and 4) the data is rendered from a vector source, the CPU is used for a longer period of time than in Method 1 (Scenario 1 and 3) where the onscreen rending consists in a jpeg decompression and bit copying. The average time in seconds spent in query is almost constant over all the domain with the exception of zoom levels that overview the map. This is due to the fact that overviews contain information stored in several vector regions.

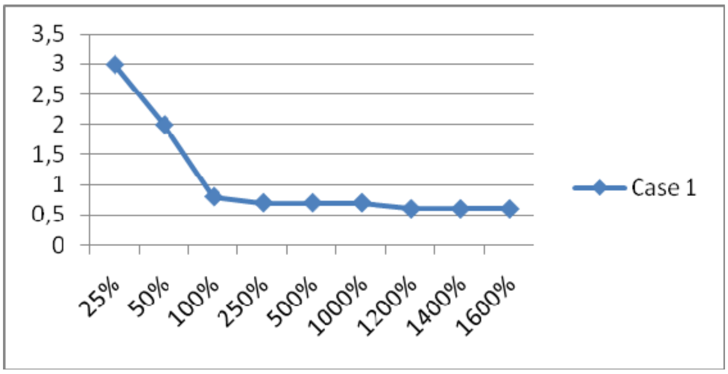

Figure 2. Average time in second spent in query for different zoom levels for Scenario 2

When using a real life data set (Case 2) we don't notice any change in the query time (vs. Case 1). The response time is similar because at every zoom level the time needed depends only on the number of regions needed to render the response.

Both approaches have their own strengths and weakness. The raster caching of entire zoom levels offers great performance as long as you are within the limits of a zoom level that is cached and poor outside these limits. At zoom levels that overview the map the disk space required to store the pre rastered sections of the map is low but a closer look zoom level will require a much larger disk footprint. The growth of the file size is the second power exponential of the multiplication index. Going outside the cached zoom levels the rendering time greatly increases. This method has great performance when working with low multiplication indexes.

The splitting of the vector image in several vector sectors has its advantages when working with high multiplication indexes. The number of vector sectors needed in rendering a region decreases with multiplication indexes because the probability of the region to be found on the border of two or more regions decreases with the relative difference between the size of the sector and the size of the requested region. The performance of the method is directly linked to the number of sectors used. In overview zoom levels the method performs poorly as it needs to query several sectors that are caught within the field of view. Zoom levels with high multiplication indexes perform very well because they can be rendered with a low number of sectors. This method can be improved to work well if a raster cache is used to store results for later use in situations where the number of sectors involved in rendering is larger than a defined value.

By using one of the two method mentioned above the downside of having no spatial index to improve searching in the EMF file can be overcome within acceptable performance limits.

4. The Network Plan

The Network Plan contains all the important information about the description of the network. The layer is structured in several sub-layers each of them embedding a model for describing and monitoring the infrastructure based on specific transmission mediums.

The rendering system for the Network Plan is based on vector graphics. Because the application has to be used in troubleshooting the physical network problems it has to be able to run in insolated mode (without requiring any network access). As previously discussed, the City Plan is already stored locally and rarely updated (the only time a network connection is needed) this meaning that the Network Plan also has to work in a limited offline mode.

Another issue investigated in [8] reveals a scalability problem when applications are working with spatial databases in remote locations. This reveals the need to implement a spatial indexing algorithm in the local application in order to cope with large number of queries (e.g. like the one generated by moving mouse over different objects and indentifying which of them is hovered over by the cursor). Implementing a spatial indexing algorithm make sense only if the data which is indexed is accessible locally, either in RAM or worst case on the hard-disk.

These two issues sustain the idea of creating a local data storage system that enables part of the data that is vital to be stored locally. The data will be synchronized with the remote database only when changes appear either locally or on the remote side in the database as a result of another client working with the application. Having the network description data locally enables the application to work desynchronized in restricted mode when the network connection becomes unavailable. The synchronization uses a versioning mechanism that stores the timestamp of the latest change at data row level. The timestamp is always assigned based on the database server's current time and the process is done by using data triggers that update the information stored in the version field. The database also keeps the timestamp associated with the last change performed in the data table.

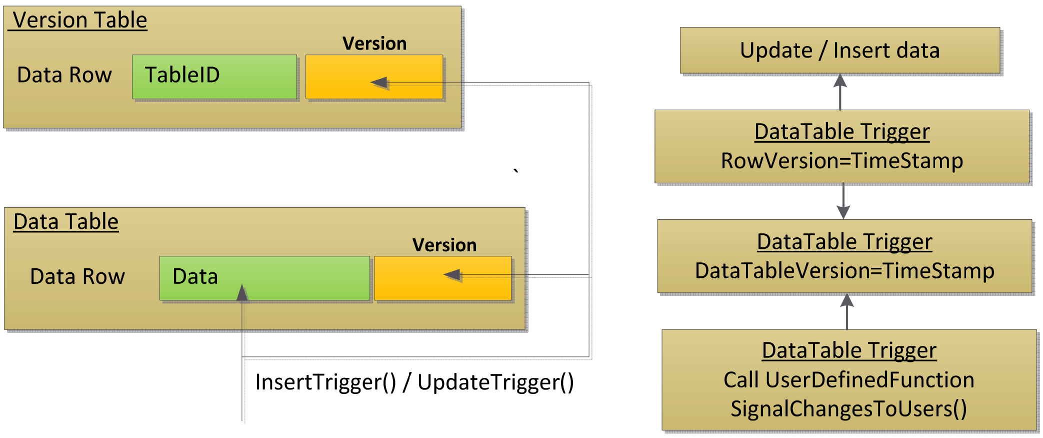

Figure 3. Database schema example

The synchronization process is very fast. The application checks the Version Table and asks which data table has a version number greater than the version in the local storage. If such a data table is detected, a query is immediately run on the data table to retrieve all entries that have a higher version number. After retrieving the differences, the local database is synchronized: the new entries are added and the old ones are updated/removed.

5. Network management system implementation

The application allows the accurate description of physical network equipments by modeling key technology elements that compose the network infrastructure. The modeled technologies are fiber optics, copper cable infrastructure based on UTP twisted pairs, WiFi point to point links and analogue CTV coaxial infrastructure. Each technology can be used for data transmission and has its own specific equipments.

Fiber optic modeling

Fiber optics infrastructure can be composed out of several major components: fiber optics cable, optical distribution frames, enclosures, media convertors, passive optical multiplexers and demultiplexers.

Modeling Fiber Optic Cabling

Fiber Optic is used as a medium for telecommunication and networking because it is flexible and can be bundled as cables. Fiber-optic cabling is made either of glass or plastic and used to guide light impulses. It is especially advantageous for long-distance communications, because light propagates through the fiber with little attenuation compared to electrical cables. This allows long distances to be spanned with few repeaters.

Current transmission standards have yet to approach the physical potential bandwidth of this medium.

Generally, an optic cable contains multiple buffers that in turn contain several threads that are the actual carriers of light. Fiber optic cables can be broadly classified into two types, based on the source that emits the light: single-mode and multimode. Single-mode optical fiber carries a single ray of light, usually emitted from a laser. Because the laser light is unidirectional and travels down the center of the fiber, this type of fiber can transmit optical pulses for very long distances. Multimode fiber typically uses LED emitters that do not create a single coherent light wave. Instead, light from a LED diode enters the multimode fiber at different angles.

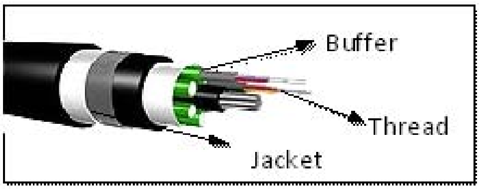

Figure 4. Fiber optic structure

In order to convert light impulses to electric signals special equipments named media convertors are used. In order to communicate, two hosts need at least two wires in order to achieve full duplex communication: one for TX transmission and one for receiving RX. Dual fiber media convertors use two threads, one for transferring RX and one for TX. Media convertors that use Wavelength Division Multiplexing (WDM) technology use two or more different wavelengths for transferring light impulses; by doing this they can achieve multiple connections over the same fiber thread.

The fiber optic model is able to store information about: geographical coordinate of cable positioning, cable reserves present on different point of the fiber, information about the type of the fiber, number of buffers, number of threads and the connections at each end of the thread.

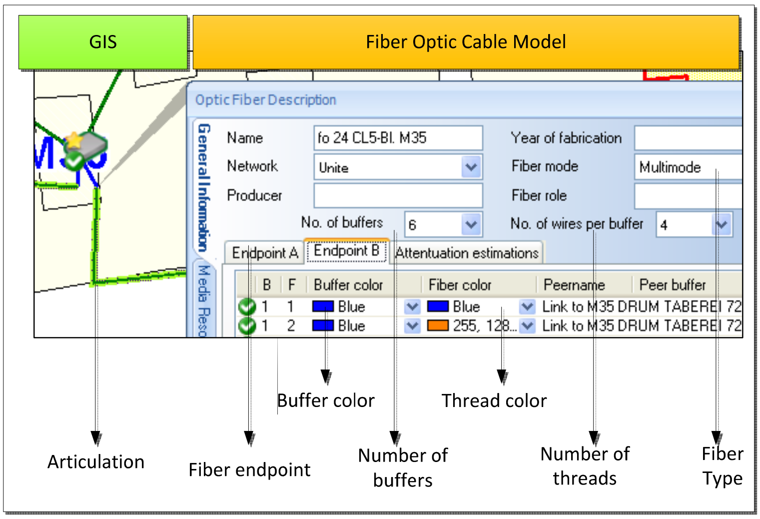

Figure 5. Fiber optic cable model

Modeling an ODF - Optical distribution frames

An optical distribution frame is a fiber optic management unit used to organize the fiber optic cable connections. It is usually used indoor and the can take any size, from small, like a patch panel, to big frames. Linking two optical cables normally is done by using one of two splicing techniques: fusion splicing and mechanical splicing. Fusion splicing works by generating a high voltage electric arc that welds two fiber threads together. Mechanical splicing works by bringing two fiber threads heads close together in a gel that has a refraction index similar to the one of the optic cable allowing light to pass thought with a limited attenuation of the signal.

An optical distribution frame has two important parts: the inside splicing diskette and the pigtails that are factory connected to the outside ports and the outside port panel.

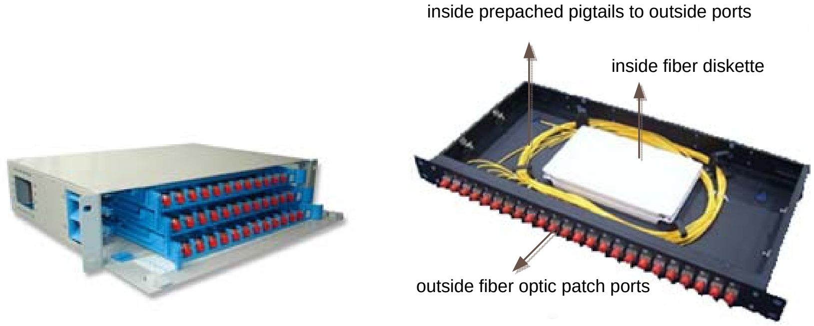

Figure 6. Figure Optical distribution frame structure

Each pigtail is welded to a fiber thread.

The benefits of using an optical distribution frame are important. First, when physically rerouting a circuit, an engineer will change only the position of a patch cable. If there is no ODF present the engineer would need an optical splicing machine. Second, the ODF reduces de complexity of the wiring - the technician will not need to know the colors of the buffer and thread in the fiber to identify a portion of the circuit. All he needs to know is the port in the ODF.

In order to describe an ODF in a network monitoring system, it has to show its two main components: the inside pigtails that are welded directly to threads from a fiber and the outside optic ports where fiber patches can be connected.

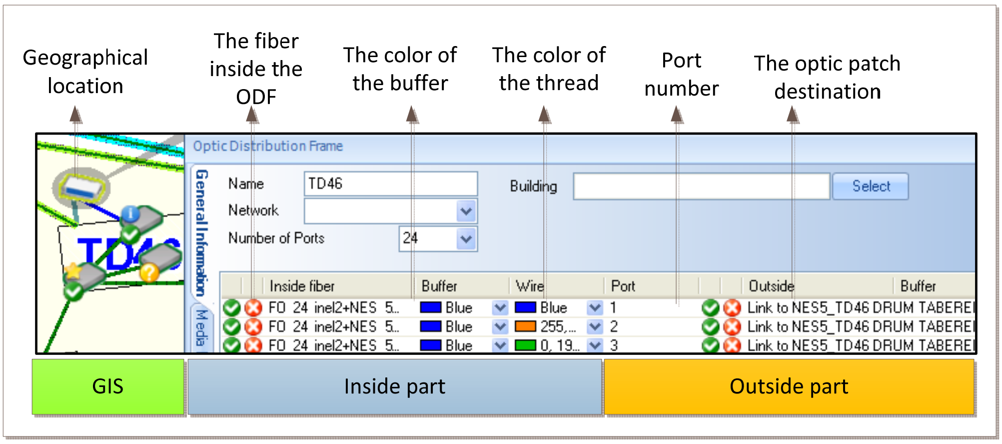

Figure 7. Optical distribution frame representation

Modeling Enclosures

The Enclosure is a fiber optic management unit used for protecting splicing from different fibers. The Enclosure has on its bottom several sockets used for incoming fiber cables that are spliced inside. On the inside, the Enclosure has several splicing diskettes that hold the welded fibers tight in place that would be otherwise vulnerable to mechanical shocks.

Figure 8. Enclosure

The Enclosure is modeled as a vector of one on one weld entries. Each weld contains two joined threads that are exactly identified by a fiber unique id and name, buffer color and thread color and a diskette number that identifies the diskette that contains the splices.

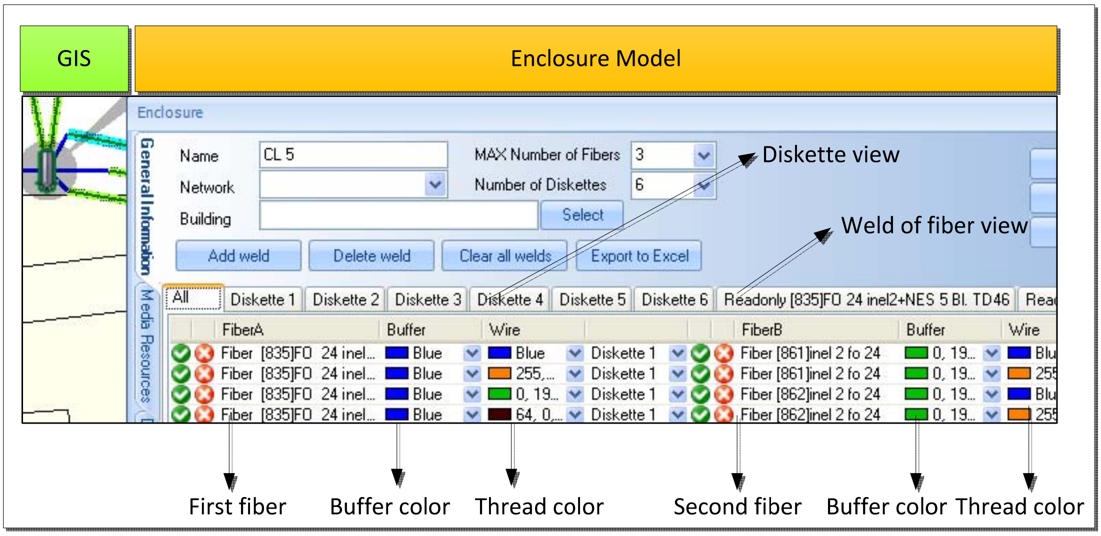

Figure 9. Optical enclosure representation

Media convertors

A media converter is a device that is used to change electrical signals on a copper cable to optical impulses that run on fiber, letting a company introduce fiber in the network without making other changes. Because of their capability, media convertors are used by networks that are in the process of upgrading from copper to fiber, and are unable to do it all at once. They have to do it incrementally either because the network is in production or they don't have the budget, manpower or the time needed.

Media converters are also used for connecting the last-mile copper connection to the optical metropolitan-area networks. The vast majority of the personal desktop computers and laptops do not have a built-in optical network card, and rely instead on the current Ethernet standard working on UTP twisted pair copper wires.

Media converters work on the physical layer of the network in accordance to the OSI stack; they do not interfere with upper-level protocol information. This lets them preserve quality of service and Layer 3 switching. They receive data signals from one media and convert them to another while remaining invisible to data traffic and other net devices. They act like bridges connecting two different communication mediums without changing the nature of the network.

The simplest form, a media converter is a small device with two media-dependent interfaces and a power supply. It can be installed almost anywhere in a network. The style of connector depends on the selection of media to be converted by the unit. In a Fast Ethernet environment, a 100Base-TX to 100Base-FX Media Converter connects a 100Base-TX twisted-pair device to a 100Base-FX compliant single or multimode fiber port that has a fiber-optic connector. In Gigabit Ethernet, a media converter is commonly deployed to convert multimode to single-mode fiber. The number of optical connectors used for fibers also varies depending on the technology used. A WDM media convertor usually uses only one fiber. Media convertor shelters can be used in places in which media convertors are packed in large numbers. These shelters are chassis-style devices designed to be rack - mounted that can be managed with SNMP.

The media convertors are modeled as network devices that contain two ports. One of the two ports is an electrical Ethernet type port such as 1000BASE-T, 1000BASE-CX, 100BASE-TX, while the other one is an optical port such as: 1000BASE-SX multi-mode fiber that is rarely used anymore, 1000BASE-LX single-mode fiber, 10GBASE-LR or 10GBASE-ER.

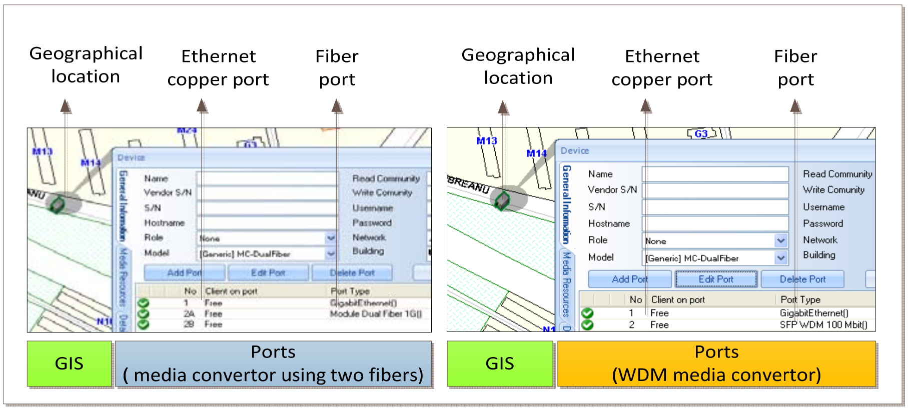

Figure 10. Device characteristics

Fiber attenuation model

The attenuation represents the extinction of a signal traveling on the transmission medium. The attenuations are present on all mediums. The increase in attenuation can render the transmission inefficient or even inoperational.

In fiber optics, the increase of attenuation can cause malfunction in media converting equipments and failure to establish connectivity. Large fiber attenuation, which necessitates the use of amplification systems, can be caused by several factors such as:

- A combination of material absorption in the fiber optic cable either from poor technology or production faults, or because of physical stresses to the fiber or material ageing.
- Physical phenomenon like Rayleigh scattering that states that light or other electromagnetic waves traveling trough transparent solid, liquid or gas materials can be scattered by particles that have a smaller size than the wavelength of the wave or like Mie scattering [1].
- Imperfect splicing either due technology (mechanical splicing has higher attenuation) or due to poor quality splicing machine or mishandle.

The material absorption for silica, the major component in fiber glass, is around 0.03 dB/km. Modern fiber producing technologies only manage around 0,35 dB/km. The attenuation is also influenced by the wavelength of the light used as a carrier. Higher wavelengths experience lower attenuation: for example, at 1310 nm, in accordance to the ITU-G.652, the attenuation is 0,35 dB/km; at a higher wavelength of 1625 nm, the attenuation decreases to 0,25 dB/km.

Attenuation is also affected by the number of splices. In general telecom companies accept as a valid splice a splice that has an attenuation lower than 0,1 dB/km.

Copper wired and WiFi infrastructure modeling

a) Copper cables

Copper cables represent the standard method for interconnecting devices. Old cable types like narrow coaxial for token rings or other like technologies are not supported, instead focusing on the twisted pairs. The actual cable contains 4 pairs of twisted copper wires, hence the name: twisted pair. The wires inside are twisted to prevent crosstalk between neighboring pairs and to cancel out external electromagnetic interference.

There are two main classifiers of copper cables: category (CATx) and type (UTP/STP/FTP).

The cable's category is actually a design specification regarding its characteristics: impedance, propagation speed and delay, skew, maximum tensile load, wire size, cable thickness, bandwidth rating and so on. Mostly used categories are Cat5, Cat5e and Cat6. Cat5/Cat5e for example is meant for 100Mbps communication, while Cat6 is certified for 1Gbps.

The type of the cable is determined by its internal structure. UTP (Unshielded Twisted Pair) is the simplest cable type, containing only the four twisted pairs that are again twisted amongst themselves sheltered by an light plastic outer jacket. UTP is the most used cable type in the present due to its cheap cost and high flexibility, being used mostly indoors. FTP stands for Foiled Twisted Pair due to its extra metallic foil that covers the twisted pairs. This gives the cable a much stronger electromagnetic resistance, allowing safe usage both indoors and outdoors. The STP cable (Shielded Twisted Pair) offers even more protection, shielding each of the individual pairs with a conductive jacket. This shielding, while providing more EM and crosstalk proofing does increase its bulkiness and cost. STP is used mostly outdoors and in high EM environments.

The GIS takes into account these characteristics as the user needs to know where cables are installed and their type and category. For example, besides its physical position, it is important to know if a failed link that will be replaced is a Cat6 STP or a simple Cat5e UTP cable. Moreover, Gigabit ports need to be interconnected with the correct cable type, otherwise the link will cause difficult to detect problems.

b) WiFi

Wireless technology plays an essential part of today Internet enabled networks. They allow users the possibility to move in a limited environment without losing network connectivity. Because accessing the wireless network can be done with relative ease this method of connecting the network has drawn many computer users especially the ones using laptops. This technology is used especially as a last mile solution. Although their benefits are notable there are several factors that make them unsafe for different security reasons and sometime unusable if not configured properly.

It is important to know the working frequency channels used by the WiFi enabled devices in order to ensure that they do not interfere. The proposed network management solution enables the network administrator to store information about the software configuration used for the equipment, monitor the activity of point to point links and equipments, bring up alerts when two access point devices operate on the same channel are too close together and thus might the effects of interference.

6. User interface

The user interface requirements are similar to all applications. The interface has to be clear and easy to be understood and used. It also has to be consistent throughout the application. The interface model is intuitive and resembles the way network technicians working in the field organize this type of data. Technologies like drag and drop are used to easily identify and link together transmission mediums and equipments.

7. Conclusions and future developments

The implemented network management system is able to accurately describe most of the components that make up the infrastructure of an internet data carrier and internet service provider. This is an extremely important issue for the Internet Service Providers that need to have up-to-date information about their infrastructure. Based on this information they can implement development strategies for updating and expanding the infrastructure with the help of the network management system. The importance of having a complete view of the infrastructure is also vital when troubleshooting network problems. In practice there is a big gap between the network administrators that are interested only in the logical configuration of the network, monitoring only network transmission performance parameters (round trip time, number of flows, packet loss, malformed packets such as runts, MTU, bandwidth) between hosts, ignoring altogether the physical layer, and the field technician that is responsible for maintaining the infrastructure from the physical point of view that often doesn't use any monitoring tools. The proposed network management system is designed to cover this gap by documenting the infrastructure. Based on that documentation and on the transmission parameter gathered automatically, an estimate can be given about how much of the physical infrastructure is working and how well. Using different algorithms for spectral analysis as seen in [5] the information gathered from the network is synthesized and presented in an easily interpreted format.

In comparison to other solutions like the hardware ones using NoC (networks on chip) the technology presented in [6] is less expensive and offers a controllable degree of redundancy.

In accordance to the ISO / OSI network layers the proposed system covers the physical layer, data link layer and parts of the network layer. In the current configuration the system only analyzes the functionality at network layer assuming that the physical topology is the same with the logical topology. In real life in some cases the physical configuration can be totally different than the logical configuration. There are technologies such as: VLAN - virtual local area networks that allow logical level segregation, MPLS that is able to create "virtual links" between distant nodes, VPN - virtual private networks and IP tunneling technologies that allow two hosts to logically communicate as if they are alone in the network and directly connected. All these technologies do not affect the accuracy of the physical layer description but they affect the monitoring algorithm and also the prediction algorithm. Future improvements will be aimed at resolving these issues. Preprocessing of vector GIS maps with techniques similar to the ones presented in [7] can be added in order to reduce the complexity of the vector maps.

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