A GIS-BASED METHODOLOGY FOR DESIGNING WIRELESS LINKS

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Abstract: Wireless technology is frequently used in military networks for establishing communication in areas characterized by non-uniform terrain morphology (i.e., mountains, islands, etc.) where mobile military units have to be moved and for creating also a security back-up network easily to be used for emergency situations (i.e., an enemy's sabotage). Towards the exploitation of the wireless technology, the paper presents a methodology for specifying the wireless links, which constitute the backbone of a wireless military network. Although the presented methodology concerns the design of a military-purposed wireless network, it can be easily generalized in order to be applied in other types of wireless networks (e.g. commercial, corporative, pilot networks, etc.). An application of the proposed methodology is also discussed in the paper.

Key-Words: GIS, Military Networks, Line of Sight, Propagation Models, Simulation

1 Introduction

A mobile tactical network can be characterized by transmission/reception requirements constantly changing for security and confidentiality aspects, distances between some important military nodes also changing due to operational reasons, potential physical objects intentionally obstructing the communication channels for a period of time (i.e., enemy's sabotage), and military applications requiring different bandwidth and latency guarantees [1-3]. Traditional network design techniques can offer efficient spectrum and bandwidth utilization [4], but they do not consider military aspects such as geographical locations, strict requirements for security and confidentiality, continual communication between some crucial military network nodes (e.g., the network nodes situated in the headquarters of a military organization), network viability in cases where many links fail simultaneously and special military user's demands or needs or purposes, etc.

In military networks, a common purpose constitutes the inter-connection of a number of locations (for example a number of involved military units) with known co-ordinates. The design of an extended tactical network with point-to-point wireless connections is a complex and non-trivial procedure where many parameters have to be considered. Among them, the selection of the optimum sites for the installation of the antennas is of major importance. In this direction, the usage of Geographical Information Systems (GIS) that co-operate with digitized maps of the area under study can provide useful tools for efficient network design [5]. Moreover, GIS can facilitate the network service/support of mobile military units. Considering that accuracy constitutes a major demand in military communications, the resolution of the underlying digitized maps as well as the provided information (i.e., terrain data, vegetation, buildings etc.) have to be selected carefully according to the specific military applications and services.

The paper presents a GIS-based methodology for designing an extended tactical wireless network consisting of point-to-point links. The methodology exploiting the appropriate GIS functions of ARC/INFO [6] facilitates the definition of the locations of the base stations as well as the optimum sites that offer adequate coverage supposing certain mobility tactical scenarios for some military units. It is noted that the proposed procedure has been proved quite efficient for the selection of the minimum number of intermediate

wireless nodes in several complicated cases. As soon as the topology of the tactical wireless network is decided, the evaluation of the proposed links is performed using appropriate propagation models.

The rest of the paper is organized as follows: Section 2 discusses the proposed methodology for efficiently designing the backbone wireless links of a military network. Section 3 provides an application of the presented methodology towards the design of a military network. Finally, Section 4 concludes the paper providing also some issues for future work.

2 The Proposed Methodology

The discussed design methodology provides a set of basic guidelines for the specification of the wireless links, which constitute a wireless military network. Although the presented methodology concerns the design of a military-purposed wireless network, it can be easily generalized in order to be applied in other types of wireless networks (e.g. commercial, corporative, pilot networks, etc.).

The goal of the proposed design methodology is to satisfy some special features of a wireless military network, such as the need/demand for:

- secure and reliable wireless links,
- routing flexibility, which can guarantee alternative routing paths,
- easily accessible base stations totally controlled by the military authorities, and
- the best radio coverage for mobile outfits.

It is also important to be highlighted the fact that for a military-purposed wireless network, some links can be more critical and sensitive from others (e.g. the wireless links, which connect the headquarters of a military organization). In addition, the implementation costs do not constitute for a military network such a critical design factor as they are for other types of networks.

Passing now to the proposed methodology, two major design phases can be identified: the *pre-design* and the *actual design*. The pre-design phase gives to the actual design phase all the necessary information input consisting in requirements and data. The requirements can concern issues such as special routing demands (e.g., due to geographical reasons the direct wireless inter-connections between some military networking nodes are not allowed), certain mobility scenarios for some mobile outfits, special criteria for the selection of network's locations, etc. The data can include digitized maps, information about the terrain, the vegetation and the buildings of potential network's locations, the co-ordinates of some critical military networking nodes, etc.

In the actual design phase, the network designer has to define the exact locations of the base stations of the under-design wireless military network. These locations have to satisfy all the pre-design phase requirements. The proposed design methodology recommends for the specification of the base stations locations the usage of GIS-tools.

The specification process includes the following three steps:

1. First selection of base stations locations using empiric and intuitive criteria (e.g. mountains, hills, or even the terraces of high altitude buildings can constitute ideal locations for base stations) as well as input from the pre-design phase (e.g. the co-ordinates of some military units).
2. For the selected locations, the Line Of Sight (LOS) and the coverage areas are examined using the appropriate GIS functions. Check for the satisfaction of the requirements setting up in the pre-design phase. In case of satisfaction, the exact locations of base stations have been defined. In other case, the specification process continues in step (3).
3. The selected locations are moved according to the results of the GIS functions. In addition, the insertion of some auxiliary intermediate networking nodes is considered. The process returns to step (2).

The last stage of the proposed methodology concerns the evaluation of the specified wireless links. Towards this direction, known propagation models [7] as well as simulation platforms (such as OPNET [8], COMNET) can be used. Typical input for these tools constitutes the antennas and terrain elevation heights, the base station distances, data taking into account the curvature of earth, etc.

3 Application Scenario

In this section an application scenario is analyzed to demonstrate the advantages of the presented methodology. It is noted that the following procedure has been based on real terrain data that were available in digital maps of the area under study.

The geographical area under consideration is shown in Figure 1, where it is assumed that the purpose is to interconnect *Islands A* and *B*. Because of the topographical characteristics of the certain area, it is easy to verify, by means of a GIS, that a number of locations are suitable to establish line-of-sight between the two islands. Nevertheless, it is reasonable to select the transmission site of *Island A* on the mountainous area found at the Northwest side (see Figure 1).

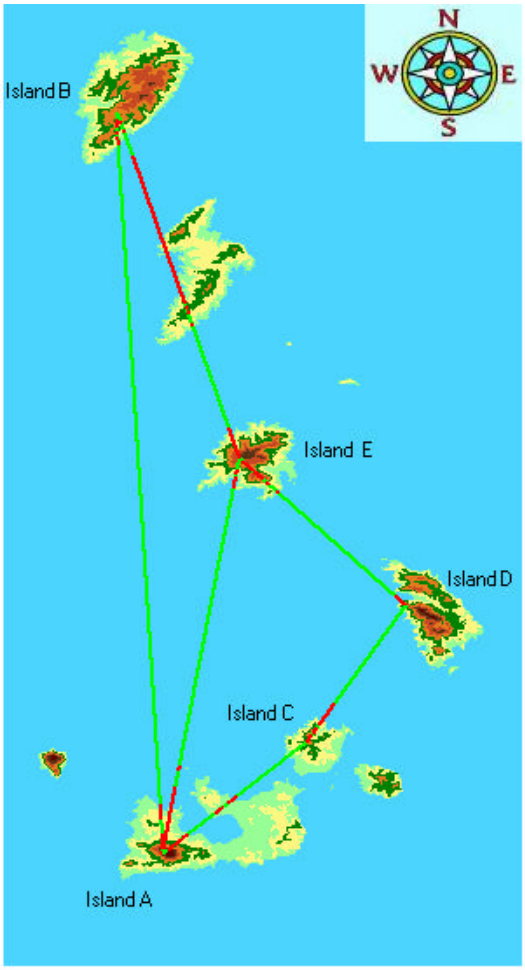

Figure 1. Visibility area for different locations under the consideration area

In that case, although that line-of-sight is established, the distance is rather large to ensure an acceptable link quality and hence, it is preferable to use a number of intermediate hops as illustrated also in Figure 1. Moreover, in that way alternative routing of the information can be achieved offering advanced security against failure of a certain link. This issue appears critical in military networks. Generally, adding a number of intermediate nodes increases the design complexity. Here the advantages of the presented methodology arise: when digital terrain data are available, the use of GIS simplifies the procedure and significantly reduces the time of the network planning, since suitable sites can be easily located and critical parameters (like length of the link, minimum antenna heights etc) can be calculated with sufficient accuracy.

Besides the interconnection of the islands, it is supposed that communication has to be established with a mobile military unit within a specific geographical area. The investigation of this test case will be applied to *Island A* Generally speaking, the best solution would be the identification of a single transmitting node, which will establish communication with remote areas (i.e. between *Island A* and *B*) offering, at the same time, adequate coverage of the nearby region. Nevertheless, in areas with non-uniform terrain morphology this is not applicable in most cases.

The selection of the transmitting sites is restricted by a number of parameters like the existence of streets to access the locations or the permission to install the transmitting equipment. As a result, only a small number of locations are available and yet the best solution has to be drawn.

In this scenario it is supposed that three locations are available in *Island A*, namely *Nodes A1*, *A2* and *A3* shown in Figure 2. It is noted that all of them establish line-of-sight with the neighboring islands (*B*, *C*, *D* and *E*). Then, using the proper functions of GIS, the visibility area of a certain point can be extracted, assuming a specific elevation height. In that way, the areas that preserve line-of-sight with a certain Node can be located. The described procedure was applied for *Nodes A1*, *A2* and *A3* and the results are shown in Figures 3, 4 and 5.

Figure 2. Location of Nodes A1, A2 and A3 in Island A.

Figure 3. Visibility area of Node A1

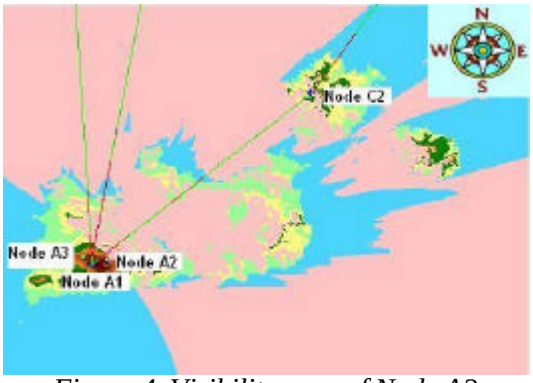

Figure 4. Visibility area of Node A2

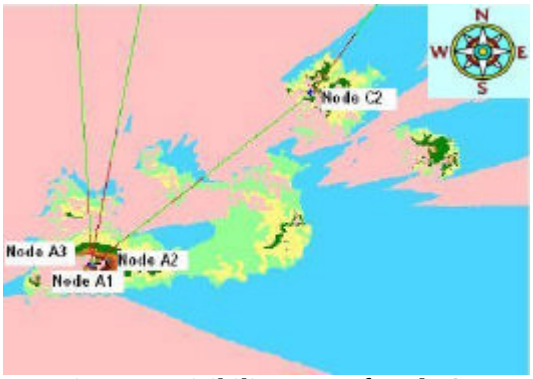

Figure 5. Visibility area of Node A3

As demonstrated in Figures 3-5, none of the Nodes offer adequate coverage of the island. Hence, it is proved that making an "obvious" selection (like selecting the highest point) is not always the best solution in areas with rough terrain characteristics. It is also shown that the Northwest side of the island is only covered by *Node A1*. In the case where the coverage of this area is crucial, *Node A1* has to be used together with a second Node that offers complementary coverage of the rest of the island. The candidate locations (for the new Node) have to retain also line-of-sight with *Node A1*. Following that criterion, *Node C2* has been selected and the corresponding areas of visibility have been extracted. Figure 6 demonstrates the combined use of *Nodes A1* and *C2* where adequate coverage of the greatest part of the island is ensured.

4 Conclusion

The design of a wireless military network concerns factors (such as base stations geographical locations, data security and integrity, network viability, military regulations, etc.), which are not supposed to be critical for conventional network design. Most military radio research to date has been driven by the necessity of serving these factors. This paper presents a GIS-based methodology for efficiently designing a wireless military network. The advantages of the presented methodology are illustrated by its application towards the design of a military network in the context of a national project. Future work will move towards two directions. The first direction concerns the description of the proposed design methodology using a formal framework. The second direction refers to the integration of the proposed methodology with tools for optimal routing and network viability analysis.

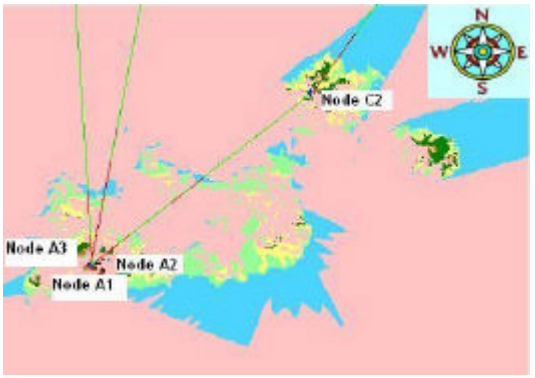

Figure 6.Obtained coverage with the combined use of nodes A1 and C2.

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