Technology Roadmapping of Wireless Local Area Networks Using Graphical Modelling System

Seda Güler[1], M. Atilla Öner[2]
[1]Marmara University, Graduate Institute of Sciences, Engineering Management Program
TR-34722 Goztepe, Istanbul, TURKEY[†]
[2]Yeditepe University, Dept. of Business Administration, TR-34755 Kayisdagi, Istanbul, TURKEY

Abstract – This paper describes a Technology Roadmap of Wireless Local Area Network (WLAN) technology, which makes use of Graphical Modelling System (GMS). Wireless networks and mobile computing are experiencing an explosive growth, with millions of users in the past few years. With current demands, WLANs are being developed to provide better quality and higher bandwidth to users in a limited geographical area. The objective of building a roadmap for WLANs is to stimulate timely and effective development of the infrastructure required to be successful in deploying WLAN technology. The role of the roadmap in achieving this goal is to develop and document a view of the technical capabilities required to successfully use WLANs in critical applications. The use of GMS will assist in capturing, visualizing, manipulating and managing the information contained in technology.

Key words: technology roadmap, wireless local area network, graphical modelling system.

I. INTRODUCTION

Wireless networks and mobile computing experienced explosive growth, with millions of subscribers since the late '90s. With the current demands to access information anytime and anywhere, many researchers and developers have focused on designing better and higher-bandwidth wireless networks. Wireless Local Area Networks (WLANs) are being developed to provide high bandwidth to users in a limited geographical area. As the installation and maintenance costs of traditional additions, deletions, and changes experienced in the wired LAN infrastructure increase, WLANs can be viewed as an alternative to Local Area Networks (LANs).

WLAN could be a discontinuous innovation in the wireless market with the potential to redefine the whole industry. WLAN technology could be used as an alternative to Local Area Networks and a substitute to the cellular mobile telephony (CMT) technologies to provide various mobile data and voice services. Studying this possibility through the perspective of Graphical Modelling System (GMS) is the main idea of this paper.

This paper aim at contributing to the literature on technology roadmapping by building a roadmap based on an in-depth case study of WLAN technology. In particular the question of if a roadmap can be built to point out the requirements and issues that may result in new research projects to provide reliability and a better quality of service for WLANs is addressed.

Based on reviewed literature and analysis of the WLAN case, a timed roadmap utilizing GMS is built, which defines a framework, made of technical considerations, market drivers and restraints, research and development activities.

The paper is organized as follows. In the first section WLAN technology, industry standards and different applications will be discussed. The technical, managerial and strategic considerations will follow. Technology roadmapping conception, pros and cons and the process of the roadmapping are the major focus of section three. This focus will be illustrated with the WLAN case study using GMS. Finally, a brief discussion and conclusion on the implications of WLAN and technology roadmapping will be pleaded.

II. WLAN TECHNOLOGY

A wireless LAN is a flexible data communication system implemented as an extension to or as an alternative for, a wired LAN within a building or campus. Using electromagnetic waves, WLANs transmit and receive data over the air, minimising the need for wired connections. Thus, WLANs combine data connectivity with user mobility, and through simplified configuration, enable movable LANs.

Over the last few years, WLANs have gained strong popularity in a number of vertical markets, including the health-care, retail, manufacturing, warehousing, and academic arenas. These industries have profited from the productivity gains of using hand-held terminals and notebook computers to transmit real-time information to centralised hosts for processing. Today WLANs are becoming more widely recognised as a general-purpose connectivity alternative for a broad range of business customers.

Ideally, users of wireless networks want the same services and capabilities that they have commonly experienced with wired networks. However, the wireless community faces certain challenges and constraints such as security, performance, interference and reliability.

Several technologies are attempting to address the need for wireless networking on the local-area-network level. Some of the most prominent standards in this area are Wireless Ethernet (IEEE 802.11), Bluetooth, and HomeRF. These standards were initially developed to address different needs, yet they occasionally overlap in terms of target markets.

IEEE-802.11 [1] is a proposed IEEE standard for WLAN. This project was initiated in 1990, and approved by the IEEE Standards Board in 1997. The scope of IEEE-802.11 is to develop a Medium Access Control (MAC) sublayer and Physical Layer (PHY) specification for wireless connectivity for fixed, portable and moving stations within a local area [2].

Wireless LANs use electromagnetic airwaves (radio and infrared) to communicate information from one point to another without relying on any physical connection. The data being transmitted is modulated on the radio carrier so that it can be accurately extracted at the receiving end. Once data is modulated onto the radio carrier, the radio signal occupies more than a single frequency, since the frequency or bit rate of the modulating information adds to the carrier.

Multiple radio carriers can exist in the same space at the same time without interfering with each other if the radio waves are transmitted on different radio frequencies. To extract data, a radio receiver tunes in (or selects) one radio frequency while rejecting all other radio signals on different frequencies.

In a typical WLAN configuration, a transmitter/receiver (transceiver) device, connects to the wired network from a fixed location using standard Ethernet cable. At a minimum, the transceiver receives, buffers, and transmits data between the WLAN and the wired network infrastructure. A single transceiver can support a small group of users and can function within a range of less than one hundred to several hundred feet. The transceiver (or the antenna attached to the transceiver) is usually mounted high but may be mounted essentially anywhere that is practical as long as the desired radio coverage is obtained.

End users access the WLAN through wireless LAN adapters, which are implemented as PC cards in notebook computers, or use ISA or PCI adapters in desktop computers, or fully integrated devices within handheld computers.

Bluetooth is a pure ad hoc networking protocol allowing short-range, low power, wireless communication. Ericsson originally developed it as a cable replacement for mobile phone accessories in 1996. IEEE also approves it as a new standard 802.15 [3].

The Bluetooth specification encompasses all of the advantages that ad hoc networking has to offer. Bluetooth is primarily a cable replacement technology, which explains why a 10-metre range is appropriate. Using Bluetooth multi-hop architecture, packets routed from one node to the next eventually find their destination [4].

Bluetooth technology uses frequency-hopping spread-spectrum (FHSS) communication in the 2.4-GHz industrial, scientific, and medical (ISM) band, in which unlicensed devices are permitted to communicate in most countries of the world.

HomeRF is a subset of the International Telecommunication Union (ITU) and primarily works on the development of a standard for inexpensive RF voice and data communication.

The HomeRF Working Group has developed the Shared Wireless Access Protocol (SWAP). SWAP is an industry specification that permits PCs, peripherals, cordless telephones and other devices to communicate voice and data without the usage of cables. The SWAP specification provides low cost voice and data communications in the 2.4GHz ISM band.

SWAP is similar to the CSMA/CA protocol of IEEE 802.11 but with an extension to voice traffic. The SWAP system can either operate as an adhoc network or as an infrastructure network under the control of a connection point. In an adhoc network, all stations are peers and control is distributed between the stations and supports only data. In an infrastructure network, a connection point is required so as to coordinate the system and it provides the gateway to the PSTN (Public Switched Telephone Network). Walls and floors don't cause any problem in its functionality and some security is also provided through the use of unique network IDs. It is robust, reliable, and minimizes the impact of radio interference.

Despite having different goals and target markets, all three of the mentioned standards have approximately the same technology base. In fact, the Bluetooth and HomeRF standards were derived through optimization of earlier versions of IEEE 802.11 for cost-efficiency. The simplifications include relaxed performance requirements for the physical layer (PHY)--the hardware required to implement the RF transceiver--and the simplified media-access-control (MAC) layer--the logic functionality implemented in either hardware or software that is required to maintain the link.

III. TECHNICAL CONSIDERATIONS

Technical considerations for selecting a WLAN product should not be based on a theoretical argument between one technology or another. Instead, the decision should be based on how the product meets business needs for capabilities, features, and performance. Since each customer's needs will differ, the factors discussed in this section should be weighed in their importance to these needs. Table 1 defines the technical considerations in selecting a WLAN technology.

TABLE 1. TECHNICAL FACTORS FOR SELECTING A WLAN SOLUTION

FACTOR	KEY CONSIDERATIONS
Cost	Total system cost: equipment, support, future upgrades
Performance	Data rates in the target environment
Interoperability	Communication with other WLAN systems and client devices
Security	Encryption of data transmissions
Power Management	Minimised battery changes for client devices
Service and Support	On-site service options
Response Time	Delay-management techniques in the WLAN software

A. *Cost*

A number of factors will effect the range of a WLAN device, including receiver sensitivity, transmit power output, multipath immunity, and antenna system performance (including the proper use of antenna diversity). The greater the range of WLAN devices, the fewer number of access points that will be required to cover a given building or installation. Device range may ultimately become the key factor in determining total system cost.

B. *Performance*

WLAN products typically specify the "over-the-air" data rates provided (ie., 1 or 2 Mbps). However, what matters most to the user is the actual throughput of the system in a specific application and environment. Performance tests can determine actual throughput rates in different conditions. Among the variables to consider in a throughput test are the range of the device from the access point, the system load (number and data traffic of clients using an access point), the typical packet size on the network, and the Network Operating System (NOS). Additionally, the networking software used in each implementation—including how that system supports roaming, the use of dynamic load balancing—will affect the performance of that system. Each WLAN product will provide substantially different results that may have little correlation with the data rates specified by the product vendor.

C. *Interoperability*

Until a few years ago, interoperability among WLAN systems was not possible. A particular WLAN system could communicate only with the client devices offered by the same vendor. With the introduction of the WLI Forum 2.4 GHz OpenAir Specification in 1995, customers gained the ability to purchase WLAN systems and client devices from a variety of vendors. In the future, the IEEE 802.11, Bluetooth, and HomeRF standards and specifications will provide further interoperability. WLAN systems that support interoperability give customers the freedom to choose equipment from a variety of vendors. Interoperability increases competition, a result that historically has yielded lower costs, increased features, and new product selections.

To develop an open interoperability specification the Wireless LAN Interoperability Forum (WLI Forum) was created in 1996. They are an independent panel that focuses on interoperability. The goal of the WLI Forum is to move forward in increase their membership base, increase end-user awareness about wireless LAN alternatives and certify new products/vendors. The Forum created the first IEEE 802.11 test suites for the certification of DSSS and FHSS wireless products.

D. *Security*

Security has always been a concern for wireless communications, as evidenced by the issues around interception of cellular telephone transmissions. Radios utilizing a broadcast-mode transmission scheme allow the possibility of interception by unintended receivers. Much of today's technology for spread spectrum radio was developed with exactly this problem in mind. The unique spreading patterns in DSSS transmissions were meant to be difficult to decode for a receiver that didn't know the specific pattern. Similarly, the pseudo-random hopping patterns of the frequency hopping technique were designed to avoid casual decoding. Spread spectrum radio technologies offer a great deal of protection because of these techniques. However, because interoperable WLAN solutions use the same spread spectrum patterns, this security protection is diminished.

If a customer requires more security, the IEEE 802.11 Wireless LAN standard specifies use of WEP (Wired Equivalent Privacy) encryption. This specification utilises the RSA Data Security, Inc. RC4 encryption algorithm to encrypt over-the-air data transmissions [5]. Encryption operates on top of the security provided by spread spectrum techniques. With WEP encryption, a users wireless transmission is meant to be as secure as an encrypted transmission over a wired LAN. An important consideration is that the IEEE 802.11 standard secures only over-the-air transmissions [6]. An access point will send information over the Ethernet or Token Ring network without encryption. For higher-level security requirements, customers can use an end-to-end encryption technique such as that specified by the IEEE 802.10 standard. With end-to-end encryption layered on top of the security measures in the wireless system, user data should be totally secure. The choice of security should be based on individual application requirements, and consider the trade-off of cost, performance, and complexity [5].

E. Power Management

Most WLAN client devices are battery-operated, with a limited battery life. The use of radios for communications can significantly affect battery life. Most users would not be satisfied if they had to change batteries frequently. Wireless client devices should offer advanced power management support to maximise battery life and minimise battery changes (optimally once per work shift).

F. Service and Support

Once a WLAN system is installed and operational, service and support become critical factors for the continued success of the system. Changes in system requirements, the physical environment, applications, and system components are best handled by a vendor that provides on-site service and support.

G. Response Time

Yet another consideration for determining system performance is the response time of a wireless client transaction. Response time includes host and network delay when delivering individual packets for a given system. Again, the wireless networking software will have the most substantial impact on this performance attribute. Software factors, which determine this impact, include the technique used to support roaming, use of dynamic load balancing, and the access point forwarding of buffered packets during roaming. Also important is the reliability of the WLAN device transmission at various ranges, which determines the number of packet errors and retransmission required. Different WLAN products may have wide variations in their delay performance.

IV. TECHNOLOGY ROADMAPPING

Technology roadmapping is a needs-driven technology planning process to help identify, select, and develop technology alternatives to satisfy a set of product needs [7]. It brings together a team of experts to develop a framework for organizing and presenting the critical technology-planning information to make the appropriate technology investment decisions and to support those investments.

Technology roadmaps provide a graphical framework for exploring and communicating strategic plans. They comprise a layered, time-based chart, linking market, product and technology information, enabling market opportunities and technology gaps to be identified [8].

The process aims to identify existing strengths and links within the industry and pinpoint any technology gaps, or obstacles to technology diffusion and acquisition. The process also attempts to anticipate future opportunities and threats by integrating sectoral technology needs with considerations of innovation, future investment, and enhancing business competitiveness [9].

Roadmapping can be done at either of two levels - industry or corporate. These levels require different commitments in terms of time, cost, level of effort, and complexity. However, for both levels the resulting roadmaps have the same structure - needs, critical system requirements and targets, technology areas, technology drivers and targets, technology alternatives, recommended alternatives or paths, and a roadmap report - although with different levels of detail.

Technology roadmapping process consists of three phases. The first phase involves preliminary activity without which the roadmapping probably should not be done. It identifies the markets and needs that will fuel the industry’s growth in the next three to ten years, identifies the critical technologies required to produce the goods and services demanded by these future markets, and recommend actions to ensure the industry in question is prepared to meet the future market demands. [10]

The second phase is the development of the technology roadmap. This phase define the actions required to develop and commercialize the critical technologies forecasted in phase I, identify the technology development projects that have the best potential for leading the industry to a strong position in the future markets, and finally identify the R&D funding and partnerships required to launch these projects.

The third phase is the follow-up and use of the technology roadmap, which consists basically of reviewing and updating the technology roadmap periodically as the markets and technologies evolve.

V. A TECHNOLOGY ROADMAPPING CASE STUDY ON WLANS

The roadmap is a selected set of requirements, links and R&D projects that describe the state of technology development and potential linkages in a specific area. Zurcher [11] states that the roadmap could be composed of a single requirement for a system linked to relevant R&D projects, or it could encompass multiple requirements linked to numerous projects. A graphical model visually portrays requirements, capabilities, R&D projects in different development phases, relationships between R&D projects and requirements and integration among related R&D projects [12].

This study will analyze and put forward a case study on Wireless Local Area Networks using the Graphical Modeling System through technology and market perspective. The GMS process is composed of two stages: constructing the model and analyzing the elements between the requirements and projects.

A. *Model Construction*

Model construction consists of identifying the projects and requirements for the roadmap, then identifying the relationships in between the projects and requirements. In GMS requirements are called the nodes and the relationship among the projects and requirements are called the links. R&D projects and requirements are partitioned according to the phase of development of the R&D projects and to the level of specificity of the requirements.

Since this study is an attempt on addressing the future of WLAN technology the technology roadmap model begins with the setting of industry targets to be acquired. The first target is selected to be a wider bandwidth. Bandwidth is an important of determinant in WLAN performance.

Fig. 1 represents the GMS roadmap modeling for increased bandwidth requirement and R&D project development study considering the current capability and possible future works.

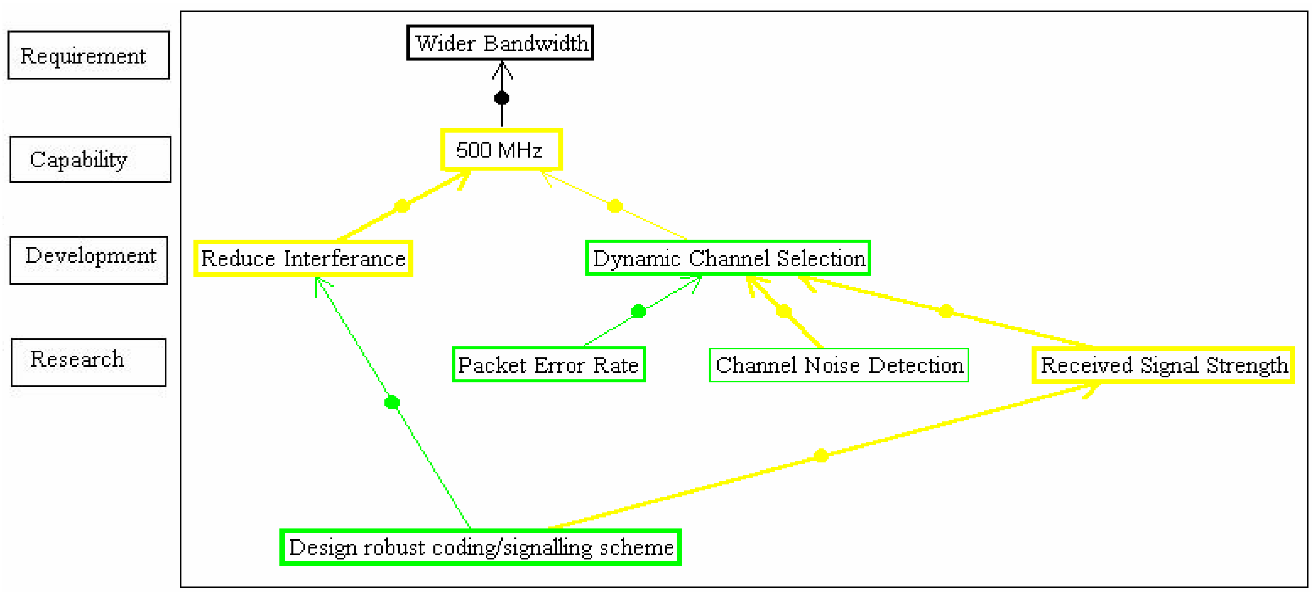

Fig.1 Bandwidth study using GMS

The two development activities are reducing the interference and dynamic channel selection. The potential impact of reducing the interference on attaining the required capability of 500MHz is highlighted by yellow colored thick link. The potential impact of dynamic channel selection to attain the 500MHz capability is highlighted by a thin yellow link. This means that dynamic channel selection and interference reducing both have moderate risks in attaining the target, but reducing the interference has more potential impact on the target. The green colored node of dynamic channel selection development program represents a low risk program when achieved without external support. Whereas with the yellow colored node reducing the interference has moderate risk when achieved without external support.

The four research activities are packet error rate, channel noise detection, received signal strength and designing robust coding and signaling scheme. Channel noise detection has the highest potential impact on dynamic channel selection and packet error rate detection has the lowest potential impact. Designing robust coding and signaling schemes has low potential impact on reducing the interference but high potential impact on received signal strength.

The utility of a technology roadmap increases as it expands to include timing information of the programs to be assessed. Addition of time dimension to the framework will result in better addressing the benefits, risks, and potential payoffs. Fig. 2 shows the time-network view of the increased bandwidth model. Products Home Network Adapter and Network Adapter are shown with big arrows, and target Product Test is shown with red arrow.

The second industry target to acquire is set to be increased range. Range is an important factor determining user satisfaction. Range capability varies based on the type of wireless bridge and antenna used as well as environmental conditions.

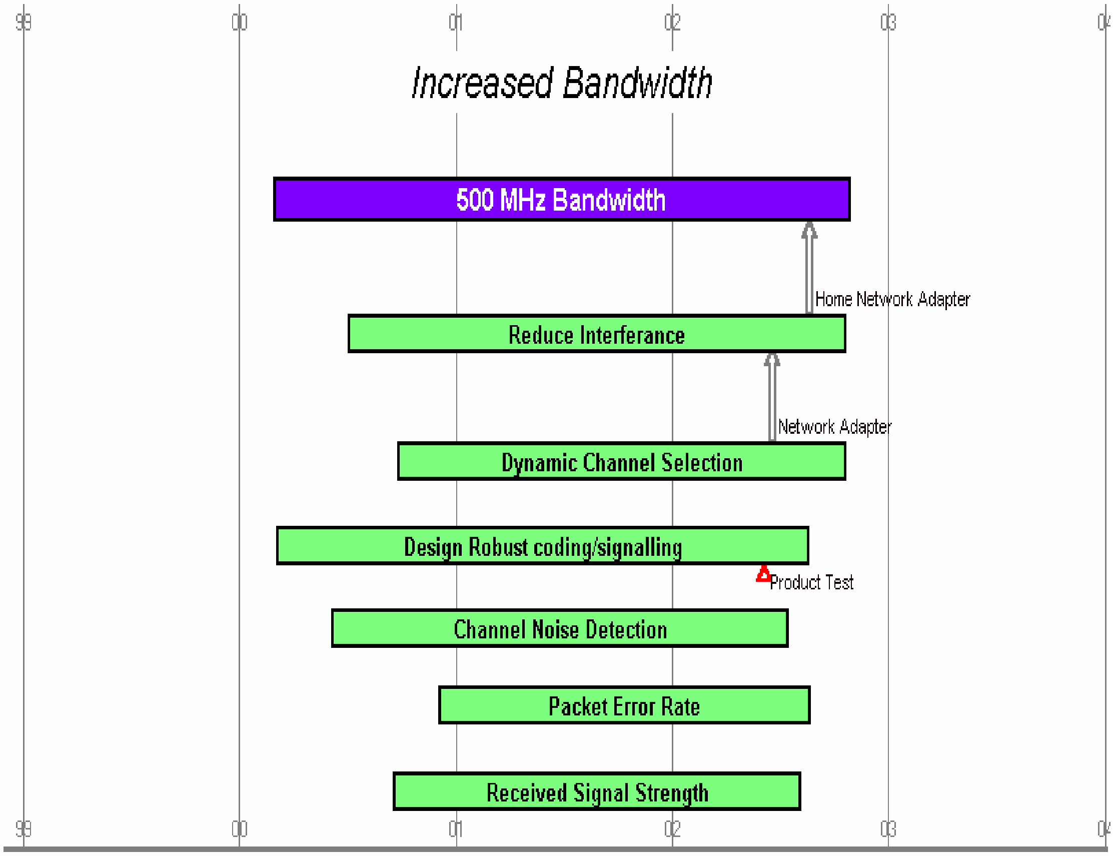

Fig. 2 Time-network view of Increased Bandwidth

Fig. 3 represents a roadmap modeling for increased range requirement and R&D project development study considering the current capability and possible future works.

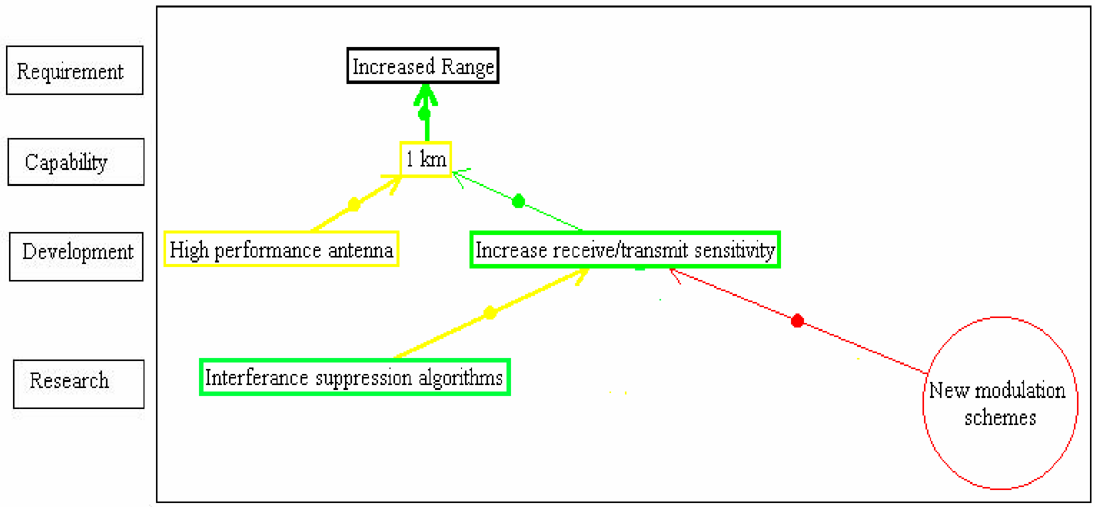

Fig.3 Range Study using GMS

The study focusing on increased range consists of two development programs, which are high performance antenna and increasing receive/transmit sensitivity. High performance antenna has a higher potential impact on target and is moderately risky, whereas increased receive/transmit sensitivity has low potential impact on target and has low risk on the achievement.

Low risk on nodes and links are shown with a green color. Moderate risky development activities are shown with yellow color. The thickness of development nodes represent the funding level of the development programs.

The research activities for the increased range are interference suppression algorithms, and new modulation schemas. Interference suppression algorithms have high and moderately risky impact on increasing the receive/transmit sensitivity, whereas new modulation schemes have lower but risky impact on receive/transmit sensitivity, which needs external support.

The research activities having low risk impact on development are shown in green color. High risked research areas are shown in red color. Circle in research area shows that new modulation schemas research area can not be performed without external support. The thickness of research nodes represent the funding level of the research areas.

Fig. 4 shows the time-network view of the increased range model developed. Product Antenna is shown with a white arrow, and target Sensitivity tests is shown with a red arrow.

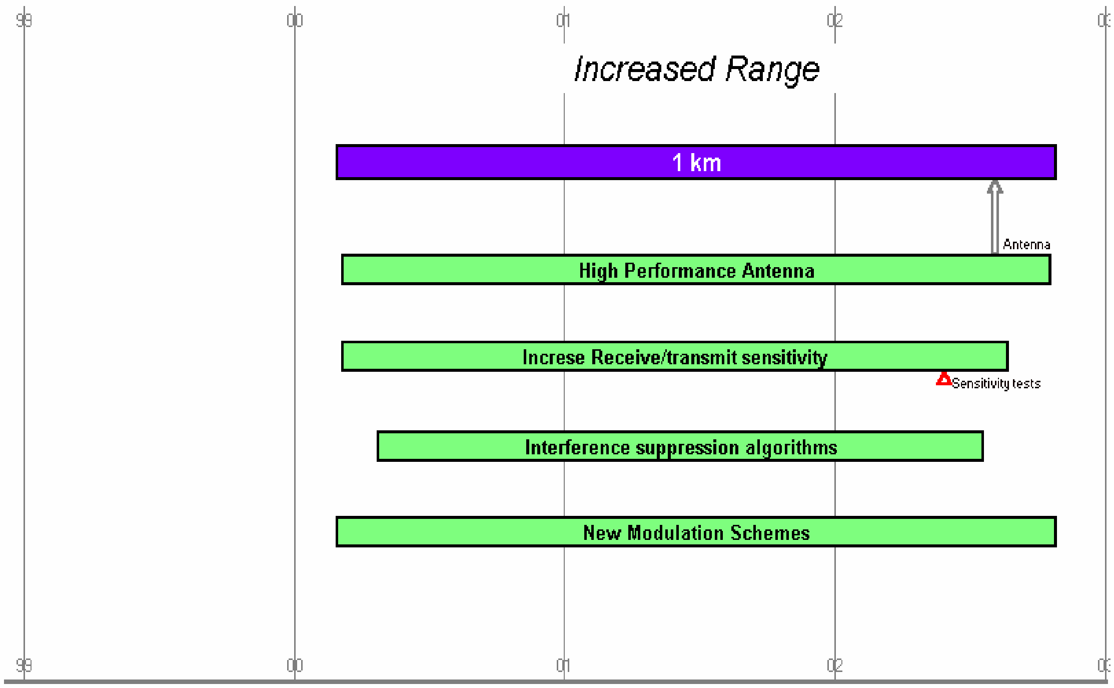

Fig. 4 Time-network view of the increased range

Third industry target to achieve is set as low power consumption. Using of high power in transmission, which requires low power consumption for devices, results in larger transmission distances. So the increased range and low power consumption targets are closely related and effect each other.

Fig. 5 represents the roadmap modelling for low power consumption requirement and R&D project development study considering the current capability and possible future works.

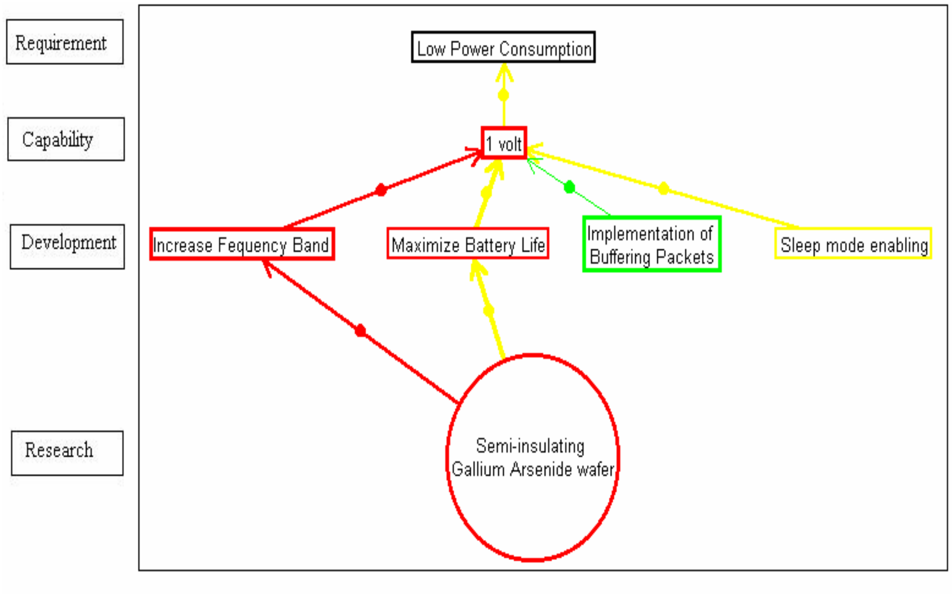

Fig.5 Power Consumption study using GMS

To attain the target capability of 1V of power consumption four development programs are defined: increasing frequency band, maximizing battery life, implementation of buffering packets and enabling of sleep mode. Increasing frequency band has a high risk and high potential impact on 1V target, whereas implementation of buffering packets has low risk and low potential impact. Maximizing battery life has the highest impact on target achievement but has a moderate risk involved.

The study on low power consumption has a risky research activity that needs external support, which is the research on semi-insulating Gallium Arsenide wafer. The research needs external support and has impact on battery life and frequency band. The potential impact on battery life is high and moderately risky, but the impact on frequency band is higher and involves high risks. Fig. 6 shows the time-network view of the low power consumption model. The Product Low power battery is shown with a white arrow and the target power consumption tests is shown with a red arrow.

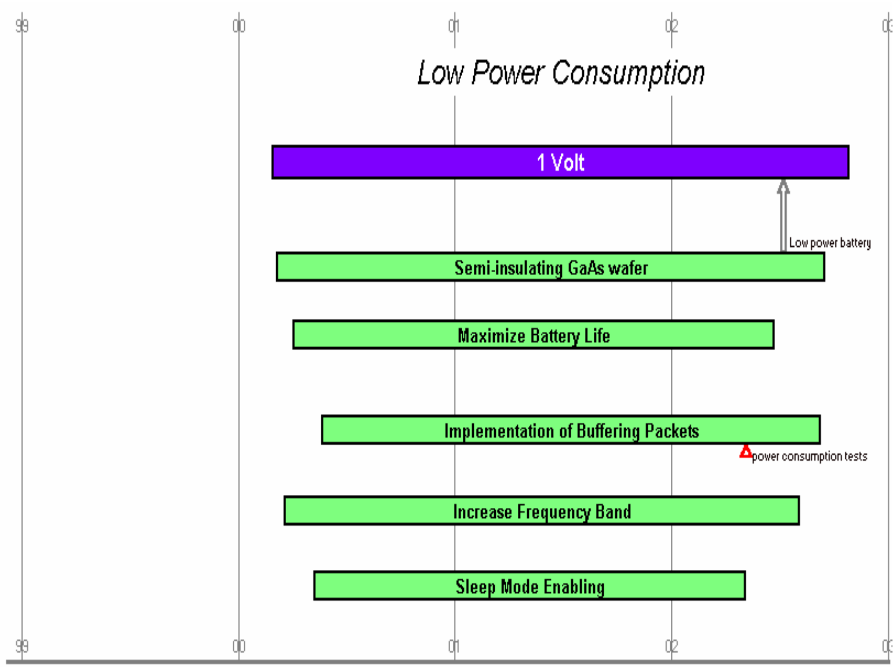

Fig. 6 Time-network view of Low Power Consumption

Increasing the throughput and thus the performance of a WLAN system is set as the last target for the technology roadmap. Since 802.11a and 802.11b standards have their own throughputs the target set for these standards are different, but the research and development projects to be developed to increase the throughput is the same for both standards.

Fig. 7 represents a roadmap modeling for increased throughput requirement and R&D project development study considering the current capability and possible future work.

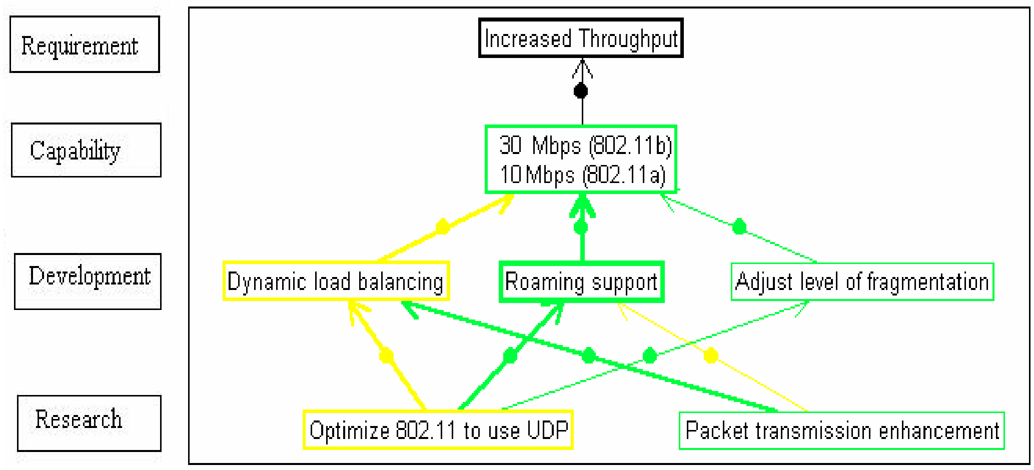

Fig. 7 Increased throughput study using GMS

There are three development programs identified to achieve the target goal of increased throughput. These are defined as dynamic load balancing, roaming support, and adjusting the level of fragmentation. Roaming support has the highest impact on the target and has a low risk of implementation. Dynamic load balancing has moderate impact on acquiring the target capability and involves moderate risks. Whereas adjusting the level of fragmentation has low impact and low risk on the achievement of target throughput. All of the development programs can be performed without the need of an external support.

The study on increased throughput identifies two research activities, which are optimizing 802.11 to use UDP and packet transmission enhancements. Optimizing 802.11 to use UDP has impact on all three development activities. The risks involved in roaming support and adjustment of level of fragmentation is low whereas dynamic load balancing is affected by moderate risk. A packet transmission enhancement has high potential impact on dynamic load balancing with a low risk involved, whereas roaming support is moderately impacted with moderate risks involved. Both of the research activities can be performed without the need of an external support.

Fig. 8 shows the time-network view of the Increased throughput model. The product 802.11 Implementation is indicated with a white arrow.

B. Model Analysis

The technology roadmap of WLAN developed using GMS follows a set of selected requirements, links and R&D projects to describe the state of desired WLAN technology. The identified roadmap study, which contains a comprehensive collection of nodes, can serve as the foundation for detailed economic studies, broad systems studies, parametric trade off studies, and etc. [13].

According to Zurcher [11] the nodes in the research and development levels represent existing or proposed research programs and development programs, respectively. The capability level nodes represent target capabilities for which there is a consensus that a successful technology roadmapping program development could result. The requirement level nodes represent existing or potential top level needs set by the organization's top management. Solid line nodes denote existing programs, projected capabilities, and existing requirements. Dotted lines represent proposed programs or research areas.

The technology roadmapping study of WLANs started with identifying the requirements, considering the question "What do we want the WLAN to be/have in the future?"

The requirement level nodes represent existing or potential top level needs. The GMS study is focused on:

1. Wider bandwidth,
2. Increased range,
3. Minimised power consumption,
4. Increased performance.

Therefore the requirement is set to be more data transmission, within a wider range and bandwidth, using low power.

In the early 2000s, the success of WLANs prompts the wireless communications community to turn its attention to other information services, like wireless data communications.

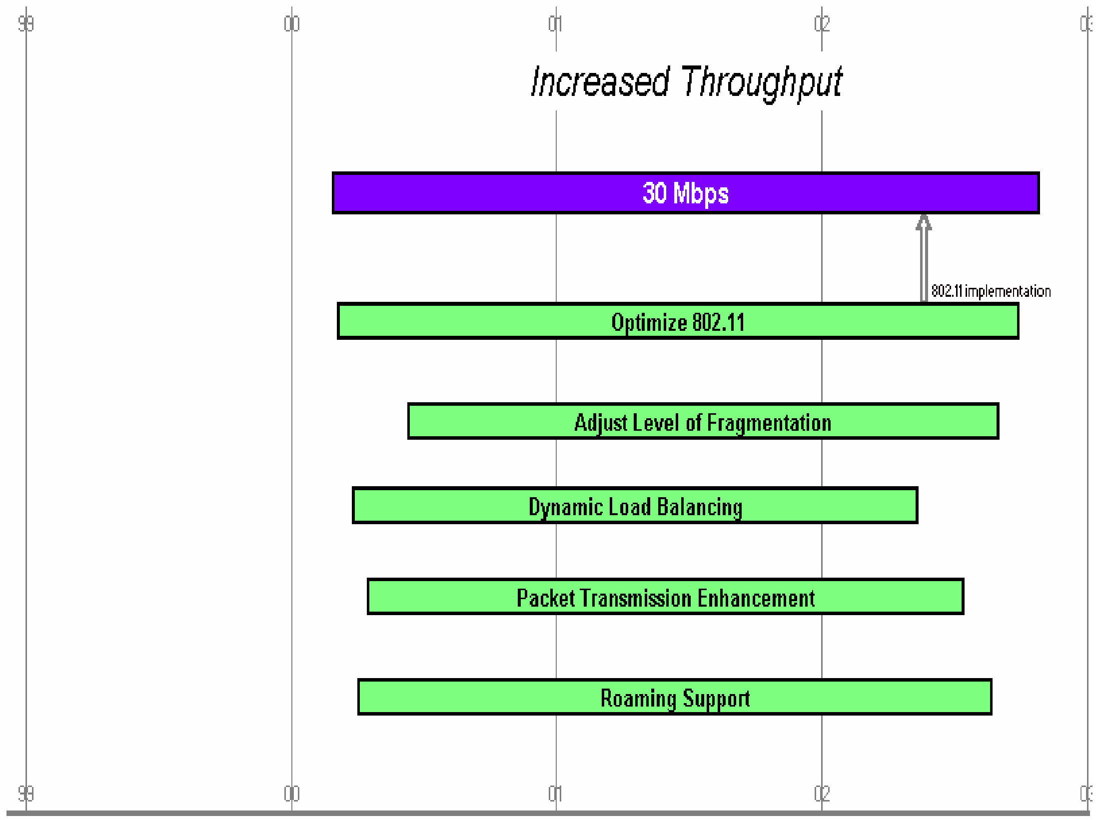

Fig. 8 Time-network view of Increased Throughput

The quality and bandwidth efficiency of wireless LAN systems depends on effective power control algorithms. A terminal and base station need to transmit enough power to deliver a useful signal to the receiver. However, excessive power causes unnecessary interference to other receivers, and in the case of transmission from a portable terminal, it drains battery energy faster than necessary.

An effective power control is essential to promote system quality and efficiency. The optimization of power control in WLAN systems is based upon the properties of the utility function for wireless data systems defined as the number of information bits delivered accurately to a receiver for each joule of energy expended by the transmitter. A power control system that maximizes the utility function maximizes the amount of information that can be transmitted by a terminal to the base station in a wireless system. The goal of the work is to provide a means of achieving a fairer operating point and also allow implementation of distributed power control using signal-to-interference ratio non-balancing.

The network keeps on broadcasting a common signal-to-interference ratio as the target. In a WLAN system, the target signal-to-interference ratio depends on the number of users simultaneously transmitting information to a base station using the same carrier frequency [14].

The number of users present in a system determines the throughput of the base station. There is a user population size that maximizes the throughput of the base station. This population size can be viewed as the capacity of a WLAN system. The availability of variable transmission rates in a wireless network raises the problem of controlling them in the most spectrally efficient way [14].

The next step is to identify the capabilities of WLAN in terms of assorted requirements. The capability level nodes represent target capabilities for which there is a consensus that successful program development could result.

The current bandwidth for IEEE 802.11a is 300MHz, where as the bandwidth for IEEE 802.11b is 83.5MHz. [15] Looking into the current bandwidth a target capability is identified as 500Mhz for 802.11a and 100MHz for 802.11b. The current range for 802.11 WLAN systems is approximately 100m. [14]. Looking into the current capability a target capability of 1km is set to achieve. Power consumption has a current capability of approximately 5V [16]. The target capability therefore is set to 1V. The current capability for throughput (also determines the performance of the system) is 22.6Mbps for IEEE 802.11b and 5.1Mbps for IEEE 802.11a [17]. Therefore looking into the current capability the target capability is set to 30Mbps for 802.11b and 10Mbps for IEEE 802.11a.

The targets set for all the requirements take the technology drivers and restraints into consideration. The target requirements reflect the dynamic impact of market, technology, and regulatory drivers and combine the key industry goals. The success of the roadmap will be defined in terms of target acquirement.

After the desired target capabilities are identified the development level is to be constructed. The nodes in this level represent existing or proposed development programs. The potential impact of a node is represented by the thickness of the links. The thicker links represent higher impacts on the capability attainment, where as thinner links represent lower impacts. The colors of links represent the risks impacting the development program. Red on link means high risk, yellow is moderate risk, and where as green is low risk. The colors in nodes also represent the risks in attaining the targets. The thickness of the node, however, represent the funding level of the program. A thicker node means adequately funded program, where as thinner nodes mean moderately or under-funded programs.

The nodes in research level represent existing or proposed research programs. The potential impact of a research node is represented again by the thickness of the links. The thicker links represent higher impacts on the capability accomplishment, where as thinner links represent lower impacts. The colors of links represent the risks impacting the research program. Red on link means high risk, yellow is moderate risk, and green is low risk. The colors in nodes also represent the risks in acquiring the targets. The thickness of the node, however, represent the funding level of the program. A thicker node means adequately funded program, where as thinner nodes mean moderately or under-funded programs.

C. Conclusion on Model Construction and Analysis

Conceptually, the developed network is greater than the sum of its nodes. The developed network includes the intelligence or inherent logic, as identified by links, which connect the nodes to each other and to the overall mission goals. As a result of the expert intelligence applied to each node, as well as links there are two important pieces of information provided by the developed network:

1. The strength of the relationships among the projects/ capabilities/ requirements and the subsequent identification of high obstacle and low obstacle paths.
2. Identification of R&D projects being concluded external to the organization, and their importance to successful attainment of the organization goals.

The developed network with its enhanced information content serves to promote communication among all the participants and provide a strong basis for further analysis and decision making.

Time-network view of the model adds an additional dimension to the acquisition program: the time dimension. The time-network view is a time-enhanced view of displaying the network. This view enables graphical representation of the time attributes of the objects represented by nodes, and of the relationships represented by links, in a Graphical Model.

VI. DISCUSSION AND CONCLUSIONS

This paper presented the design, development, implementation, and analysis of a wireless local area network's technology roadmap. The study set out first to describe and define the wireless local area networks and technology roadmapping in general. The framework was then used to analyse the current state of the industry and the technology.

This study synthesises the wireless LAN technology roadmapping with a graphics tool, Graphical Modelling System (GMS) a graphical user interface for roadmap building. The study aiming at designing, implementing, monitoring and supporting of an efficient roadmap throughout the way of WLAN technology provides a realistic, believable bottom-up simulation approach modelling of WLAN. Through the use of GMS the strengths and weaknesses of the developing a WLAN system are revealed and it is hoped that this technology roadmap study, as an initial effort, will be the motivator for other efforts to develop new WLAN systems and benefit other designs and as an inspiration to develop additional dedicated, focused roadmaps.

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