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ANALYSIS FOR EFFECTIVE IMPLEMENTATION OF AD HOC NETWORKS

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Abstract

Deployed in 1990's, Mobile Ad-hoc networks have been widely researched for many years. Mobile Ad-hoc Networks are a collection of two or more devices equipped with wireless communications and networking capability. These devices can communicate with other nodes that immediately within their radio range or one that is outside their radio range. For the later, the nodes should deploy an intermediate node to be the router to route the packet from the source toward the destination. Although since 1990s', lots of research has been done on this particular field, it has often been questioned as to whether the architecture of Mobile Ad-hoc Networks is a fundamental flawed architecture. The main reason for the argument is that Mobile Ad-hoc Networks are almost never used in practice, almost every wireless network nodes communicate to base-station and access points instead of co-operating to forward packets hop-by-hop. After giving many evidences and analysis, we could see that the key technologies of Wireless Ad-hoc Networks were not implemented as well as we expect. That is to say, many problems are inherently unsolvable. Thus, in this paper we stress on the need of refining our approach towards Adhoc networks by discussing the general problems faced and by proposing their solutions.

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Keywords: Hierarchical Networks, MANETs, Routing.

1. INTRODUCTION

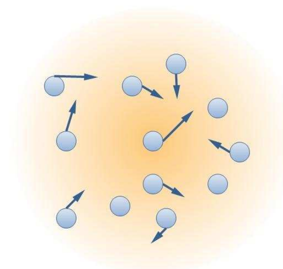

Figure 1: Ad Hoc Network: Nodes mover randomly in different direction and different speeds

Over the last couple of years wireless communication has become of such fundamental importance that a world without it is no longer imaginable for many of us. Ad hoc networks, which cover a variety of network paradigms for specific purposes, such as mobile ad hoc networks, sensor networks, vehicular networks, underwater networks, underground networks, personal area networks, and home networks, promise a broad range of applications in civilian, commercial, and military areas.[5] Beyond the established technologies such as mobile phones and WLAN, new approaches to wireless communication are emerging; one of them are so called ad hoc and sensor networks. Ad hoc and sensor networks are formed by autonomous nodes communicating via radio without any additional backbone infrastructure. Typically, if two nodes are not within mutual transmission range, they communicate through intermediate nodes relaying their message, i.e., the communication infrastructure is provided by the devices themselves. In view of the great potential of ad hoc and sensor networks in a variety of application scenarios such as disaster relief, community mesh networks, monitoring and surveillance, or data gathering, it is not surprising that there has recently been a flurry of research activity in the field. In our group a broad variety of the different aspects and open questions of ad hoc and sensor networks are investigated. Topics of interest include medium access control, routing, topology control, deployment strategies and energy efficient system design. There is no fixed base station to use as gateway nodes.In these, nodes are free to directly signal to other nodes within the scope of communication.Here nodes are free to move in any direction. In multi-hop wireless networks, communication between two end nodes is carried out through a number of intermediate nodes whose function is to relay information from one point to another. [4]

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Routing of messages from a source to one or multiple destinations is a fundamental building block for all applications in the domain of ad hoc and sensor networks. In most cases, the only means to divulge information is by routing, either as unicast, any cast, multicast, or broadcast. Whereas there are standard approaches for the latter, it is much more challenging to implement efficient single destination routing, any casting, and multicasting. Efficiency is not only concerned with how fast a message is delivered, but also how much overhead the algorithm generates. We proposed and analysed a labelled routing scheme designed to cope with the limitations and requirements of wireless devices: With small routing tables of bounded size, we provide close to optimal unicasting, and constant approximations to any cast and multicast .Using knowledge of the position of nodes in the network is a popular approach to routing in ad hoc and sensor networks. Algorithms incorporating location information are known as Geographic or Geometric routing protocols. For systems where each node is equipped with a location sensing device geographic routing is considered to be the most efficient and scalable routing paradigm. However, these geographic routing algorithms assume the sender to know the position of the destination node. This introduces a high storage overhead if each node keeps track of the position of all other nodes. Even more challenging is the situation with mobile nodes. In a mobile ad hoc network (MANET), nodes may be moving continuously and their location can change even while messages are being routed towards them. To tackle this problem we introduced a routing framework called MLS in which each node can send messages to any other node without knowing the position of the destination node. The routing (lookup) algorithm works hand in hand with a publish algorithm, through which moving nodes announce their current location on a hierarchical data structure. [3]

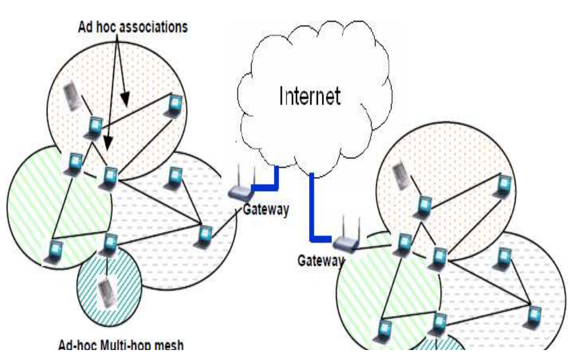

Figure 2: Ad-hoc Mesh network with multi-hop connections to gateway

We formally proved that the paths computed by MLS are only a small constant factor longer than the optimal routes. The amortized message cost induced by the publish algorithm of a moving node is thereby locally bounded by the distance the node moved. Furthermore this was the first work determining the maximum node speed to allow concurrent lookup and node movement. Providing entity authentication and authenticated key exchange among nodes are both target objectives in securing ad hoc networks. Ad hoc networks are temporary networks because they are formed to fulfil a special purpose and cease to exist after fulfilling this purpose. Mobile devices might arbitrarily join or leave the network at any

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time, thus ad hoc networks have a dynamic infrastructure. Most mobile devices use radio or infrared frequencies for their communications which leads to a very limited transmission range. Usually the transmission range is increased by using multi-hop routing paths. In that case a device sends its packets to its neighbour devices, i.e. devices that are in transmission range. Those neighbour nodes then forward the packets to their neighbours until the packets reach their destination. The most distinguishing property of ad hoc networks is that the networks are self-organized. The various security goals availability, confidentiality, integrity, authentication and non-repudiation.[4] The Defence Advanced Research Projects Agency (DARPA) was among the original patrons of the mote idea. One of the initial mote ideas implemented for DARPA allows motes to sense battlefield conditions .For example, imagine that a commander wants to be able to detect truck movement in a remote area. An airplane flies over the area and scatters thousands of motes, each one equipped with a magnetometer, a vibration sensor and a GPS receiver. The battery-operated motes are dropped at a density of one every 100 feet (30 meters) or so. Each mote wakes up, senses its position and then sends out a radio signal to find its neighbours. All of the motes in the area create a giant, amorphous network that can collect data. Data funnels through the network and arrives at a collection node, which has a powerful radio able to transmit a signal many miles. When an enemy truck drives through the area, the motes that detect it transmit their location and their sensor readings. Neighbouring motes pick up the transmissions and forward them to their neighbours and so on, until the signals arrive at the collection node and are transmitted to the commander. The commander can now display the data on a screen and see, in real time, the path that the truck is following through the field of motes. Then a **remotely-piloted vehicle** can fly over the truck, make sure it belongs to the enemy and drop a bomb to destroy it.

This might seem like an awful lot of trouble to go to, until you realize the system that these motes replace. In the past, the tool a commander used to prevent truck or troop movement through a remote area has been land mines. Soldiers would lace the area with thousands of anti-truck or anti-personnel mines. Anyone moving through the area -- friend or foe -- is blown up. Another problem, of course, is that long after the conflict is over the mines are still active and deadly -- lying in wait to claim the limbs and even lives of any passer-by. According to this UNICEF report, over the last 30 years, landmines have killed or maimed more than 1 million people -- many of whom are children. With motes, what is left behind after a war are tiny, completely harmless sensors. Since motes consume so little power, the batteries would last a year or two. Then, the motes would simply go silent presenting no physical threat to civilians nearby.

This concept of ad hoc networks -- formed by hundreds or thousands of motes that communicate with each other and pass data along from one to another -- is extremely powerful. Here are several examples of the concept at work:

- A farmer, vineyard owner, or ecologist could equip motes with sensors that detect temperature, humidity, etc., making each mote a mini weather station. Scattered throughout a field, vineyard or forest, these motes would allow the tracking of micro-climates.[2]
- A biologist could equip an endangered animal with a collar containing a move that senses position, temperature, etc. As the animal moves around, the mote collects and stores data from the sensors. In the animal's environment, the biologists could place zones or strips with data collection motes. When the animal wanders into one of these zones, the mote in the collar would dump its data to the ad hoc network in the zone, which would then transmit it to the biologist.[2]
- Motes placed every 100 feet on a highway and equipped with sensors to detect traffic flow could help police recognize where an accident has stopped traffic. Because no wires are needed, the cost of installation would be relatively low.[2]

2. RELATED WORK

Ad Hoc Networks (ANETs) are communication networks in which all nodes are mobile and communicate with each other via wireless connections. There is no fixed infrastructure. All nodes are equal and there is no central control or overview. There are no designated routers: all nodes can serve as routers for each other, and data packets are forwarded from node to node in a multi-hop fashion. A MANET can be useful in all those situations in which for necessity or other practical or economic reasons no fixed network infrastructure is available, such as military activities in enemy territory, disaster recovery operations or big conference rooms. On the other hand, it is quite clear that in the more technologically advanced societies in the near future networking will be pervasive and highly heterogeneous: mobile ad hoc networks, body area networks, GSM/GPRS networks, satellite networks, the wired Internet will all be somehow interconnected, creating a sort of gigantic hybrid mobile ad hoc network.

Routing, which is the task of directing data flows from sources to destinations maximizing network performance, is at the very core of the functioning of every network, and in particularly of MANETs. On the other hand, routing is particularly challenging in MANETs. Due to the mobility of the nodes, as well as the continual arrival and departure of nodes/users, the topology of the network changes constantly. On the hand, it is necessary to keep finding new paths to reach the newly arrived users; while on the other hand, paths which were initially efficient can quickly become inefficient or even infeasible. Moreover, the practical bandwidth of the network is limited by the fact that the wireless medium is shared,

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such that appropriate complex protocols must be used at the MAC layer (e.g., the popular IEEE 802.11a/b/g).[1]

Nowadays, the information technology will be mainly based on wireless technology, the conventional mobile network and cellular are still, in some sense, limited by their need for infrastructure for instance based station, routers and so on. For the Mobile Ad Hoc Network, this final limitation is eliminated, and the Ad Hoc Network are the key in the evolution of wireless network and the Ad Hoc Network are typically composed of equal node which communication over wireless link without any central control. Although military tactical communication is still considered as the primary application for Ad Hoc Networks and commercial interest in this type of networks continues to grow. And all the applications such as rescue mission in time of natural disasters, law enforcement operation, and commercial as rescue and in the sensor network are few commercial examples, but in this time it's become very important in our life and they become use it. The Ad Hoc Networking application is not new one and the original can be traced back to the Defence Advanced Research Projects Agency (DARPA) Packet Radio Networking (PRNET) project in 1972[1, 2, 3] which evolved into the survivable adaptive radio networks (SURAN) program [4] .which was primarily inspired by the efficiency of the packet switching technology for instance the store/forward routing and then bandwidth sharing, it's possible application in the mobile Ah Hoc Networks environments. as well as in the Packet Radio Networking devises like Repeaters and Routers and so on, were all mobile although mobility was so limited in that time, theses advanced protocol was consider good in the 1970s.after few years advance in Micro Electronics technology and it's was possible to integrate all the nodes and also the network devices into a single unit Called Ad Hoc Nodes. And then the advance such as the flexibility, resilience also mobility and independence of fixed infrastructure, and in that time they so interesting to use it immediately among military battlefield, Ad hoc networks have played an important role in military applications and related research efforts, for example, the global mobile information systems (GloMo) program [5] and the near-term digital radio (NTDR) [6] program. And also has been the increase in the police, commercial sector and rescue agencies in use of such networks under disorganized environments. Ad Hoc network research stayed long time in the realm of the military. And in the middle of 1990s with advice of commercial radio technology and the wireless became aware of the great advantages of Mobile Ad Hoc networks outside the military battlefield domain, and then another critical constraint for routing activities is given by the on-board power/energy. A typical mobile device has limited on-board power, which must be used wisely. Increasing the power used for radio transmission/reception widen the radio range and so improves connectivity, which is essential to guarantee routing and, more in general, network functioning. Therefore, a good balance must be found between the local connectivity and the amount of energy used to provide such level of connectivity. [1]

Figure 3: Simple ad hoc network: nodes are represented as laptops, personal digital assistant (PDA) or robots, but they may be any node device with communication capabilities

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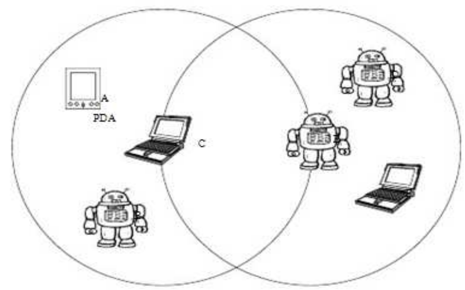

Design of ad hoc networks is extremely challenging. Fig. shows a simple ad hoc network. In this network, the two circles resemble the communication ranges of nodes C and E. In this scenario, for node A to communicate to node D, which is out of its range, its message needs to be routed through nodes C and E. Suppose that node E is receiving message from node D. Node C will not be able to sense that there is transmission in progress and if it tries to transmit to node E, without access control, collisions will occur (this is known as the hidden node problem). Also, nodes A and C cannot communicate together if nodes D and E are communicating.

This will change if the communication range of nodes C and E are reduced slightly allowing nodes A and C to communicate without collisions while nodes D and E are communicating. Clearly, the choice of the transmission power will impact the network performance, i.e., based on the transmission power, which is directly proportional to the communication range, different nodes may or may not be able to communicate together. Consequently, power control has to be carefully designed. The problem gets more interesting as the nodes become mobile and the topology of the network becomes dynamic. Without power control, the nodes will be communicating at maximum power; this will reduce the system capacity and will shorten the battery lifetime which is highly undesirable for any standalone mobile device. In order to avoid the hidden node problem, IEEE 802.11 uses the following signal protocol: Every time a signal is to be sent, a request-to-send (RTS) message is send. If the receiving node is free, it will broadcast a clear-to-send (CTS) message. If the transmitting node hears the CTS, it will proceed to transmit its data (DATA), otherwise collision will be assumed and it will back off for a certain amount of time before trying again. After DATA is transmitted the receiving node will transmit an acknowledgment (ACK). Any node that can hear those signals, RTS-CTS-DATA-ACK, will have some information about the occupation of the channel and for how long. This is used by the MAC layer to avoid collision and hidden nodes.

3. PROBLEM DEFINATION

While building up Ad-Hoc Networks, several problems can be addressed, some as a consequence of other problems: When a node [A] inside an Ad-Hoc Network wants to send data to a second node [B], that he is not able to see, because this one is out of his transmission-rage, how can the data be transferred from [A] to [B] anyway? How can the destination [B] be identified?

How can the way from [A] to [B] be determined?

Can a technique to determine the way be found, that is scalable for small networks (1-100 nodes) medium-large networks (100-10.000 nodes) and large networks (10.000-several million nodes)?

How can a way from [A] to [B] be determined without flooding the network with inquiries? How can the number of inquiries been kept small?

How can a way from [A] to [B] be determined without knowing each node of the network? How can the information a node has to know about the network been kept small? How much a node does really have to know about the network?

Can a technique to determine the way be found that is scalable (under conditions) for networks with high change rate and low Change rate?

How can a node [A] establish cooperation relationships with the nodes that it needs to transfer data to [B]?

Is it necessary to identify malicious or unfair nodes or is there a way to accept this condition?

Can the network be kept resistant against malicious nodes? How can redundancies been introduced to be resistant?

- **Single frequency, single hop networking**: In an isolated situation, an IEEE 802.11 will the quality of wireless link between two nodes be better if transmission power is increased.
- **Multiple frequencies, multi hop networking**: When configuring the different wireless interfaces of a multi-interface integrated node to theoretically non-overlapping channels, these different links will not interfere. Capacity of a wireless network can be increases dramatically by adding multiple interfaces.
- **Power adaptation**: From previous paragraphs, we have learned, that changing power levels can lead to a more reliable link, but increasing transmit power does not necessarily increase communication quality. Furthermore, it was shown that theoretically non-interfering channels will interfere when using off-the-shelf hardware at mid to high transmit power, and that integrated systems with multiple interfaces will suffer from self-generated interference if there is no adequate antenna separation. Consequently, a single device transmitting at a relatively high output power may render all surrounding communication virtually impossible.
- **Hardware issues**: If an algorithm works on the IEEE 802.11 hardware of vendor A, it will work on the IEEE 802.11 hardware of vendor B. A recurring problem faced during tests with hardware from different vendors, is that changing an interface to some

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specific channels can result in a wireless link of bad quality. As communicating on those channels is possible using hardware from a different vendor, and bad channels stay bad when replacing hardware with an identical spare, the problem is most likely hardware related. In general, there is a big difference in stability and performance between hardware from different vendors

- **A lab environment is not a real environment**: If it works in simulation, it will work on a test-bed. If it works on a test-bed, it will work in real life. From previous paragraphs, it is clear that designing algorithms and protocols for wireless systems should preferably not be done solely by considering theory or simulations. Creating a wireless test environment in a laboratory is not an easy task. Not only does it require a lot of – sometimes costly – hardware and space, it is also time consuming. On the other hand, creating these test environments and implementing developed algorithms on actual hardware forces the researcher to develop a system close to reality. However, there is always a risk that the testing environment itself will lose its value as “real test case”, as over time wireless systems could be tuned – unintentionally – to work great in the testing environment only. This way, a solution that evaluates positive in a testing environment can at the same time be useless when deployed in an uncontrolled real-life situation. This is a frustrating experience that was witnessed before at our lab: a demonstrator to transmit video over a self-forming and self-recovering multi hop mesh/relay network was developed. After the demonstrator had proved to be working perfectly in the lab environment – even when moving the battery fed relay stations through the building – it was taken to a large hangar. Surprisingly, even with relatively short distances between the relaying hardware, and with line of sight communication, link breaks occurred frequently and maximum throughput was low. In this case, the set-up probably suffered from the absence of the waveguide effect described in [14]: there are circumstances where a wireless signal does not degrade as fast when using devices indoor, compared to using them in an open space. This example, amongst others, shows that a system should not be declared stable based on a single test environment, and certainly not based on simulations. We believe that wireless ad hoc networking protocols and systems will only be used in everyday life if their use is not limited to a specific scenario or environment. However, today, a lot of algorithms are evaluated only in simulators using a very specific test scenario and very simplified propagation models, which are not valid in real-life environment, in particular indoor environments.

4. PROPOSED MODEL

A heterogeneous hierarchical architecture:

Many problems that can be observed while bringing wireless ad hoc and mesh networking algorithms to real systems. Some of these problems are vendor related and can be solved by replacing defective hardware. One might argue that it is not the task of networking algorithms to account for these problems. However, it is inherent to the nature of wireless ad hoc networks that low-quality nodes will sooner or later join the network. Wireless systems will always be more unreliable than their wired counterparts, and therefore, algorithms must be able to detect anomalies and react accordingly. Firstly, because of interference and hardware related issues, the choice for a specific channel has an impact on the wireless link quality. Problems occur at various layers of the protocol stack when wireless links break due to changing channel conditions or failing hardware. Secondly, transmission power should be chosen wisely: neither too low nor too high. While in a static set-up, transmission power can be set manually by trial and error, there is need for automatic tuning in dynamic environments. Cross-layer protocols might provide a way to implement these control loops. Thirdly, it was shown that small devices with multiple interfaces suffer from self-generated interference. In order to overcome this problem we should focus our research on an architecture which takes this fact into consideration. An algorithm which presupposes a complete separation between multiple interfaces at end-user nodes will most likely never be able to achieve its claimed results when used in real systems. In a heterogeneous architecture, devices have distinct capabilities and technologies. In a hierarchical architecture, different nodes can belong to different logical groups, for example, backbone nodes and clients. Heterogeneous hierarchical architectures (Fig. 6) have been described in the past; however, we believe that their true potential has not been discovered yet. In [15], the authors describe (hybrid) wireless mesh architecture. In a wireless mesh network (WMN), two types of nodes are distinguished: mesh routers and mesh clients. Mesh routers hold superior properties concerning processing power, interfaces, available power and memory, enabling them to perform more complex functions. In addition, they have limited mobility compared to the clients, resulting in a wireless mesh backbone. Mesh routers can be added or removed at any time and act as gateways to other networks such as the Internet. In a hybrid WMN, mesh clients can connect to the backbone network either directly, or by using a multi hop path through other clients.

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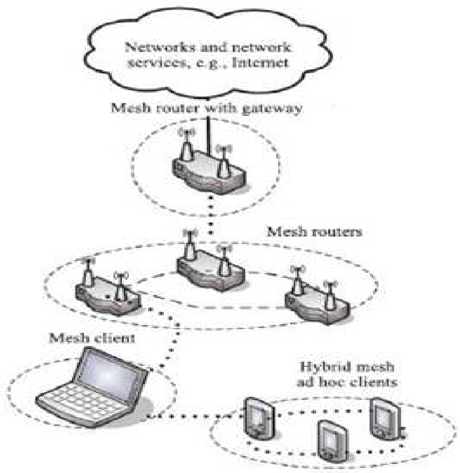

Figure 4: Heterogeneous hierarchical mesh network, i.e., a hybrid wireless mesh ad hoc network. Clients connect either directly or through another client to a mesh backbone.

Some benefits of heterogeneous hierarchical networks have been described in the past, such as an increase in coverage. However, we believe that there are more reasons why hierarchical heterogeneous architectures can help to realize robust wireless networks, and that a conscientious choice of networking architecture can help certain assumptions that are invalid for homogeneous wireless networks become valid. Most small and mobile end user devices such as PDAs or smartphones will probably only have a single (high speed) wireless network interface, using the unlicensed bands, enabled at a time, as adding interfaces is suboptimal due to the described interference problems and other limitations such as power and cost. On the other hand, the mesh routers in the backbone can and should have multiple interfaces: they can be bigger in size and antennas can adequately be separated, thereby reducing the interference problems. Additionally, they have an “unlimited” power supply as they are most likely connected to a host system with plenty of power such as a building or a truck. Faulty hardware may be used within a cooperative wireless network, resulting in decreased performance and satisfaction for the end-users. In a traditional ad hoc network, even if one user invests in high-quality hardware, he can still experience bad performance if the person he is connecting through uses faulty hardware. In a heterogeneous architecture, end users can, e.g., connect to a mesh backbone which is constructed with hardware of better quality. The nodes which are higher in the hierarchy can be more expensive, as less nodes of higher hierarchy are needed.

The Need for Cooperation

For years, researchers strictly followed a layered approach when designing networking protocols. When adopting a layered network design, different network layers can be optimized separately, and researchers optimizing a certain layer do not need to know the implementation details or exact operation of the adjoining layers. As a logical consequence of a layered network design, most network research groups historically specialized in either (one of the) upper layers of the network stack, or in the physical layer. The same can be said about wireless research groups in particular, where people developing upper layer protocols, mostly have to rely on simulators to model the behaviour of the physical layer. In order to decrease complexity and to ensure a reasonable simulation time, the

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physical models of these network simulators typically make abstraction of several complex electromagnetic phenomena. In fixed networks, the layered approach has most certainly contributed to the Internet as we know it today. Inspired by this success, traditional MANET protocol research also followed the layered paradigm. More recently, driven by the continuous search for increased reliability and performance, several authors pointed out how wireless networks can benefit from exchanging parameters between different network layers [1, 7], and researchers started exploring the use of multi-interface nodes and modified physical layers. The conceptual exploration of new wireless research fields by people originally involved in higher layers only has accelerated so fast, that it is sometimes forgotten that the physical layer models of most of the popular network simulators, such as ns-2 [18], were never designed to model the complex effects that come with these new research topics. For example, the same network simulators are now used to, among other things; simulate the use of multi-interface network nodes or cross-layer parameter exchange. Even if research groups working at the physical layer are aware of the extremely complex interference behaviour of multiple antennas placed in each other’s vicinity, this wisdom seldom makes it to people designing upper layer protocols and architectures, because of the historical separation between research groups. In our view, and from our experience, a lot of problems which are faced when implementing ad hoc and mesh network protocols cannot be explained solely by studying the upper network layers. The historical layered approach, allowed physical layer and upper layer research groups to work separately. However, as the border between physical layer and upper layers becomes faint at a conceptual level, the need to start or tighten interdisciplinary cooperation between lower and upper layer research groups has never been higher.

5. RESULTS

Assumptions that are commonly made when researching wireless ad hoc networking protocols were challenged. It was shown that, whether installing a single interface or multiple wireless interfaces at a node, real-life performance is always worse than can be expected from theoretical models or simulations. We raised questions about the usefulness of embedding multiple interfaces of the same type in a palm-size device, and argued that, in contrast to what is believed in many research papers, adjusting transmission power is not a measure of freedom but a necessity. We described how a choice of hardware affects the efficiency of algorithms, and how this influences the stability of wireless networks. In order to test the robustness of algorithms, testing on one or multiple test-beds is a necessity. However, one must keep in mind that positive test-bed results do not always imply a stable system under all circumstances. Next, we argued that heterogeneous hierarchical wireless mesh network architecture can help solving the observed problems, by reducing the need for miniaturization and providing incentives for network operators and businesses. Finally, we argued that effective cooperation between research groups working at physical layer and working at higher protocol layers might help in avoiding many of the described problems. We believe that, if protocols are developed closer to reality, and more realistic architectural choices are made at the start of a design process, the usability of ad hoc and mesh networks can drastically be improved.

6. FUTURE WORKS

It opens up many research possibilities that offer potential for further research. In the past, many other important properties of wireless networks have been studied for large scale networks. It is an

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important task to extend these results for networks with practical sizes, i.e., small-scale networks. For example, there are several other measures for network capacity such as transport capacity, information theoretic capacity, and capacity of cooperative nodes. Asymptotic analysis of these definitions has been studied extensively. It is very useful to extend these results to small-scale networks. Finite analysis can reveal the effects of network parameters on networks characteristics.

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