DTNs in the mountains: Using WSNs to analyze climbing performance

Georg von Zengen
Technische Universität
Braunschweig
Braunschweig, Germany
vonzengen@ibr.cs.tu-bs.de

Lars Wolf
Technische Universiät
Braunschweig
Braunschweig, Germany
wolf@ibr.cs.tu-bs.de

Ole Wiegmann
Technische Universität
Braunschweig
Braunschweig, Germany
o.wiegmann@tu-bs.de

Felix Büsching
Technische Universität
Braunschweig
Braunschweig, Germany
buesching@ibr.cs.tu-bs.de

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Abstract
After a day of climbing multiple routes, roped parties often have the problem to figure out what vertical distance they climbed during the day. In this paper we present a concept, a system and its evaluation that measures the vertical distance over the time. By sharing the measurements between multiple climbers the system is robust against weather influences. Another benefit is a better performance comparison between the climbers in the roped party.

Author Keywords
Wireless Sensor Networks; Delay Tolerant Networks; Sport Climbing; Radio Duty Cycle

ACM Classification Keywords
C.2.1 [Network Architecture and Design]: Wireless communication; C.2.1 [Network Architecture and Design]: Store and forward networks

Introduction
"Why did you want to climb Mount Everest?" – "Because it's there"[1]; there are many reasons to climb a mountain and history has proven that it is safer and more fun when not doing it alone. Thus, when climbing with partners you usually build a roped party. And at the end of the day you

[1] George Herbert Leigh Mallory (18 June 1886 – 8 or 9 June 1924)

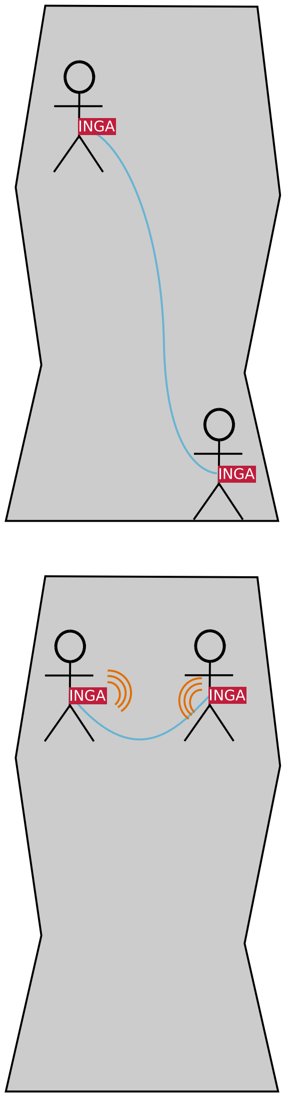

Figure 1: Two climbers using ClimbNet. In the upper part the communication is interrupted. After being closer to each other the sensor nodes start communicating

most probably want to know the exact vertical distance of your trip.

The challenges arising from this application are diverse. First the height measurements must be resistant against sudden changes in weather which may happen in mountain ranges. Normal atmospheric pressure measurements suffer from errors introduced by weather changes – especially for climbing tours that last multiple days. These errors can be compensated by combining the measurements of multiple climbers. To be able to combine these measurements a robust communication between the sensor nodes of the climbers is necessary. Such a robust communication must handle connection disruptions caused by the distance and solid rocks between the communication partners. Thus, techniques of Disruption Tolerant Networks (DTNs) fit perfectly for supporting climbers in the mountains. As shown in Figure 1 DTNs are able to reconnect and exchange the remaining data when the second climber caught up with the first one.

Another challenge caused by the application is that all nodes need to have a battery life time of multiple days while only having a minimal weight. Therefore, we present a Radio Duty Cycle (RDC) method to reduce the energy needed for the communication.

In the next section we give an overview about DTNs and Disruption Tolerant Wireless Sensor Networks (DTWSNs). Afterwards, the design and concept of our ClimbNet system is presented. In the evaluation section we show how well this implementation tackles the previously presented challenges. The last section concludes this paper.

Related Work

As pointed out in the introduction, the envisaged challenges and use cases call for a Delay or Disruption Tolerant Network (DTN). The idea of DTNs is often discussed and has it's origins in the interplanetary communication. A first specification of the architecture has been published by Cerf et al. [3]; this is the basis for many different DTN approaches. In particular, the Bundle Protocol (BP) specification [7] defines further data formats and various protocol details. Originally, the BP has been considered as an overlay network in the application layer – on top of different transport layers.

For normal PCs running the Linux operating system, a number of different open source BP implementations exist, such as IBR-DTN [6], ION[2], and DTN2[3]. They all share in common that the target platform has to be significantly more powerful than what is provided by tiny and resource scare sensor nodes.

Wireless Sensor Networks (WSNs) usually consist of low-power sensor nodes which are very limited in processing power and throughput. Thus, implementing an application layer DTN protocol on top of, e.g., a TCP/IP protocol stack leads to huge overhead.

However, 6loWDTN [1] is a DTN implementation which uses the μIPv6 stack of by the Contiki operating system for WSNs which not only adds the IP overhead but also DTN overhead.

DTNLite [4] is a TinyOS implementation of DTN concepts. DTNLite relies on existing multi-hop routing protocols and forms an overlay network, but, it does not implement the BP.

μDTN [8], in contrast, fully implements the BP. But, it is not designed as an overlay network and runs directly above the IEEE 802.15.4 MAC layer. Thus, it is resource and energy

[2] https://ion.ocp.ohiou.edu/
[3] http://sourceforge.net/projects/dtn/

efficient by design and targeted towards WSN scenarios. μDTN has, e.g., successfully deployed been in [5].

System Design

In this section we present the design of ClimbNet; an overview is shown in Figure 2. The orange boxes are the parts presented in this paper, the blue boxes are existing modules in the Contiki[4] operating system.

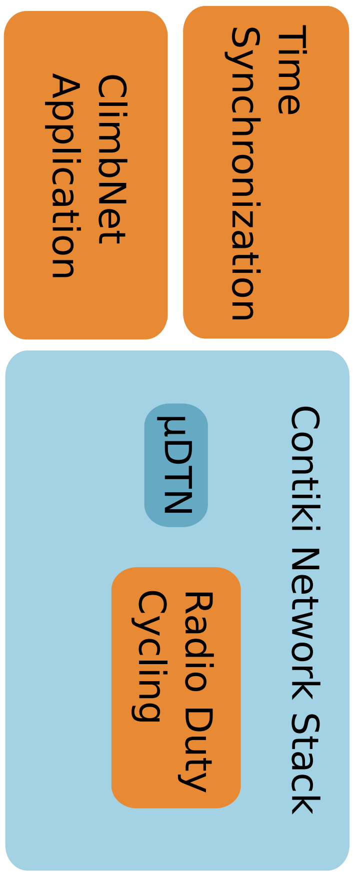

Figure 2: Architectural overview of ClimbNet. The orange parts are presented in this paper.

The first part is the ClimbNet application. It periodically measures the atmospheric pressure and saves it to a SD-Card. Each measurement has a timestamp to be able to synchronize the measurements. For the purpose of synchronization each measurement is handed to the μDTN-stack. Another task of the application is the pairing of nodes in one roped party. After pushing a button on all nodes of at the same time the nodes choose a master node on the base of the unique node ID.

The selection of a master node is also needed for the time synchronization module which itself is used by the application and the RDC. To synchronize the time of all nodes in the roped party the master node periodically transmits DTN-bundles with a very short lifetime. The lifetime of these bundles gives the lower precision bound of the time synchronization. If one of the other nodes in the roped party receives a synchronization bundle it calibrates its clock to the received one.

The third module of ClimbNet is the RDC. It helps to reduce the energy consumption of ClimbNet by switching off the radio transceiver for a certain interval of time. This is necessary to prolong the battery lifetime to up to multiple days even with small and light weight batteries. The RDC module utilizes the time synchronization to synchronize the time at which all radio transceivers in the roped party are switched on. During this time the μDTN-stack exchanges the bundles stored on the different nodes. If no communication is possible between some nodes in the roped party μDTN stores the bundles till the next time communication is possible with these nodes.

[4] http://www.contiki-os.org

All three modules of ClimbNet are involved to achieve the reliability and the energy savings which are necessary to deal with the challenges identified in the introduction. How well they perform is evaluated in the next section.

Evaluation

We implemented the described system on INGA [2] WSN nodes, shown in Figure 4, using Contiki operating system and an the enhanced μDTN [8] version as described above. As a prove of concept evaluation we used the stairways of a four story building over two hours. In this stairways we could simulate the real application scenario in terms of connection disruptions and height differences. In Figure 3 measurements of both nodes are shown. Between the minutes 80 and 100 the nodes did not have a connection because they were in different stories. The fact that even during this time the graph contains measurements proves that µDTN was able to deliver these measurement at the time the nodes had a connection again.

Conclusion

We presented an approach for distributed performance analysis for sport climbing. In the first part we identified three major challenges: measurement robustness against sudden weather changes, a disruption tolerant communication to be able to achieve the measurement robustness by combining the measurements of several sensor nodes in on roped party. The last identified challenge was the constrained energy supply.

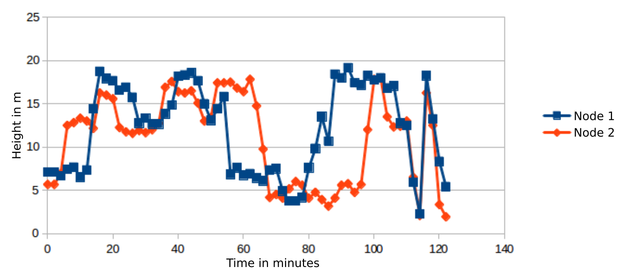

Figure 3: An evaluation of ClimbNet with two nodes in a four story building

Figure 4: The INGA sensor node used in the Evaluation to prototype ClimbNet

By combining µDTN with a time synchronization, a RDC and the actual ClimbNet application we presented a prove of concept implementation. In the evaluation we showed that this implementation is able to cope with the identified challenges.

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