Wireless Mesh Networks and Cloud Computing for Real Time Environmental Simulations

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Abstract. Predicting the influence of drinking water pumping on stream and groundwater levels is essential for sustainable water management. Given the highly dynamic nature of such systems any quantitative analysis must be based on robust and reliable modeling and simulation approaches. The paper presents a wireless mesh-network framework for environmental real time monitoring integrated with a cloud computing environment to execute the hydrogeological simulation model. The simulation results can then be used to sustainably control the pumping stations. The use case of the Emmental catchment and pumping location illustrates the feasibility and effectiveness of our approach even in harsh environmental conditions.

Keywords: wireless mesh network, cloud computing, data assimilation, environmental measurements, hydrogeological modelling and simulation, ground water abstraction.

1 Introduction

Climatic or hydrological systems are driven by highly dynamic forcing functions. Quantitative numerical frameworks such as simulation models are powerful tools to understand how these functions control the systems' response. Models are, however, always imperfect descriptions of reality and therefore model calculations increasingly deviate from the "real" physical conditions of the environmental system simulated. We can alleviate these biases by a real time integration of field data into the modeling framework (data assimilation). To accomplish this goal, we have to constantly monitor the environment through dense networks of sensors deployed over the geographical area concerned. The technology should provide high performance even in the case of harsh meteorological conditions (snow, low temperatures, fog, strong winds, etc.) and other location and infrastructure related limitations like high altitude, lack of access to the power grid, and limited accessibility (resulting in long access delays inducing significant installation/maintenance costs).

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1.1 Wireless Infrastructure

In principle, communication networks can be wired or wireless. However, building a vast and complex wired infrastructure is costly and can be technically impossible in remote locations. An alternative are radio-based technologies, which do not require expensive cabled infrastructures. Moreover, this technological choice is extremely portable, because one can easily transfer equipment from one location to another when necessary. The first choice transport technology would be GSM/UMTS, however, this solution suffers from significant shortcomings. On the one hand, it is infeasible to equip every station with a GSM/UMTS connection in the case of vast measuring networks because of the associated cost of this operation, while the provider may charge for every additional SIM card. On the other hand, there exist important locations from an environmental perspective that have poor or non-existent coverage (e.g., highly elevated regions in Swiss Alps). These drawbacks force us to search for another scalable transport technology, which may grow to reach large proportions and provide us with good coverage over remote locations. Because of recent progress in the domain of low power wireless devices we may operate Wireless Mesh Networks that allow us to significantly cut operational expenses.

Wireless Mesh Networking is an interesting communication scheme which can provide cheap Internet connectivity delivered to end users at the last mile, an easily deployable multi-hop wireless bridge between distant bases in no-direct line of sight scenarios, or a wireless back-haul connecting sensors of different purposes such as environmental monitoring or smart-home applications. To properly deploy a wireless network, there are numerous hardware and software challenges. The hardware has to be properly selected to operate under a specific power consumption regime [1], e.g., when a node is solar powered, it has to harvest and store enough energy during the day-light operation to work uninterruptedly at night. Wireless cards and antennas have to provide an acceptable signal strength to allow for high throughput, while the node setup has to provide satisfactory performance such as computational power for ciphering and packet forwarding or other network adapters able to accommodate traffic coming from wireless interfaces. The experience obtained from pilot projects installed in remote and mountainous regions for environmental monitoring [2,3] and backup backbones in urban areas illustrates that mesh networks perfectly integrate into the existing AAA (Authentication, Authorization, Accounting) [4,5], monitoring and cloud infrastructure schemes of Swiss universities. For the purpose of this work, we use Wi-Fi based backhauls to transport information from environmental sensors to Internet storage facilities in real time.

1.2 Data Storage and Monitoring

In addition to provisioning the transmission infrastructure, facilities for data storage and processing have to be developed. Our studies reveal several similarities between environmental monitoring in the wireless mesh setup and network monitoring provided by typical monitoring agents such as Nagios, Zabbix, and