WATER INFORMATION NETWORKS:
INFRASTRUCTURE FOR EFFICIENT MANAGEMENT OF WATER

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ABSTRACT

In collaboration with many stakeholders, NICTA, Australia's national information and communications research centre, conducts research in the area of Water Information Networks (WIN). In this project NICTA develops information infrastructure solutions in support of efficient water (distribution) management.

Researchers in WIN, in collaboration with Rubicon Systems Australia Pty Ltd (Rubicon) developed the idea of Total Channel Control™ (TCC™) which is patented and commercialized through Rubicon. TCC™ automates the water distribution management of large scale open canal irrigation networks with the express purpose of achieving greater efficiency. It realizes near on-demand response of gravity fed water distribution networks. As testified by a recent audit of a commercial implementation of TCC™ in the Coleambally irrigation district in New South Wales, Australia, a water distribution efficiency of 90% can be realized. Moreover gains in on-farm efficiency are simultaneously achieved due to the near "on-demand" delivery of water which allows irrigators to significantly modify their irrigation schedules, so as to better suit their local requirements.

At present, WIN researchers in collaboration with the Melbourne based UniWater research centre are considering the joint automation of on-farm irrigation and distribution canals. The goal is to realize that for every drop of water "requested" by the plants in the field, a drop of water is delivered through the distribution network from "reservoir-to-the-plant". The information infrastructure required for such a scheme is discussed.

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INTRODUCTION

In Australia irrigation accounts for 70% of all fresh water usage [1,2,3,4]. Distribution efficiency, from reservoir to farm gate, is in general poor (variably estimated between 60 to 75% [2,3,4]), not so much due to evaporation and/or seepage losses [2,3], but primarily due to understandably conservative distribution management practices. Indeed to date, undersupply leads to expensive crop losses, whereas oversupply only results in a relatively inexpensive opportunity cost (assuming, perhaps incorrectly, an abundant water supply). This observation clearly identifies the potential of automation and information management to realize efficiency gains, which is at the heart of the present contribution.

In Victoria, Australia, open irrigation canals lose about 10% of conveyed water through seepage and evaporation and about 20% to 30% is lost through bottom-end system outfalls (there are virtually no re-circulation systems in Australia) due to oversupply or is unaccounted for [2,3]. Due to the paucity of appropriate measurement systems, these efficiencies must be considered as guestimates; it is difficult to make precise statements. This too underscores the need for an appropriate information infrastructure. When water is a cheap commodity, there is no motivation to be more efficient in water distribution, but the pressures from population growth, industrialization and climate change [1] are clearly changing this. The need for a more sustainable approach to water management is clearly felt world-wide. Here we discuss an information infrastructure enabling efficient water distribution across large scale irrigation networks. Our discussion is informed by the results achieved with this information infrastructure in the Coleambally Irrigation District, Australia. The annual bulk water license for this district is 620 gigaliter of water. It services nearly 100,000 hectares of farm land and stock water for nearly 300,000 hectares. By December 2007, all 326 control structures operating 481 km of supply canal as well as over 100 on-farm outlets (flows from 15 ML/day to 6,000 ML/day) will be under TCC™ operation. So far, the system under TCC™ has reported a water distribution efficiency of 89% [5]. TCC™ is patented technology [6,7], commercialised through Rubicon. Much of the modelling, control and system theory implemented in this technology has been published [8-16] in the specialised literature.

The paper is organized as follows. We briefly consider the high level requirements for an information infrastructure capable of supporting efficient water management across an entire irrigation district. Next we consider implementation issues, and some of the important side benefits automation brings with it. We underscore the need of integrating the information infrastructure in support of operational management with the overall business information systems to achieve the true potential of the proposed technology. In ongoing work we are developing sensor networks in support of on-farm water management and integrate these into the overall water and economic management of an irrigation district.

WATER INFORMATION NETWORKS

It is clear from an overall systems engineering perspective that water management should happen at the level of an entire water basin, also clearly advocated in [1].

A basic need for the sustainable exploitation of a (water) resource is to be able to account for it in an accurate and timely manner, so that alternative regimes can be appropriately explored and a cost/benefit analysis performed. From a spatial point of view, water volumes in dams/lakes/reservoirs; flows in canals/rivers and flow from borehole/pump infrastructure and water levels in rivers/canals are the basic measurements that are needed to be able to arrive at a mass balance account.

Besides the spatial aspects, we must consider the time scales over which decisions have to be made, or the time scales over which we can expect significant changes in the main variables of interest. Irrigation is not only challenging from a spatial scale point of view, the inherent time scales equally span several orders of magnitude. On the longest time scale (years to decades) the main issue is sustainability: how best to use the limited, renewable water resource. This involves the development of appropriate policy and pricing mechanisms, as well as the appropriate civil infrastructure (dams, canals, recycling plants) and information infrastructure (sensors, actuators, communication network, Supervisory Control and Data Acquisition (SCADA) and data base systems). On a yearly and seasonal basis the allocation of water volumes are to be decided according to specific economic and environmental requirements. Existing civil and information infrastructure must be maintained and upgraded as required. On a weekly and daily basis irrigation schedules are planned to meet farming/cropping needs. In support of this, plant based and soil based sensors, appropriately networked, to monitor crop water needs are ideal. On an hourly time scale individual pools react (water levels and flow change in response to variable demand and in-flow conditions). On the minute time scale, a communication network links canal water levels and flow measurements with the regulating structures to maintain management objectives: water flows over regulating structures, and water levels at specified structures, as well as supply flows to the farm gate and pump flows. Moreover, sensor and actuator variables must be monitored to enable (preventive) maintenance and to ensure a graceful degradation in performance when sensors, actuators, or the communication network develop failures. Proper integration of the information from the fastest time scale to the longest time scale, across the spatial domain of an irrigation district or basin, requires a carefully planned data structure. The longevity and value of the information demands that all measurements are properly labeled and linked with the sensor calibration data. The latter must be kept current, and maintained (sensorML may play an important role here [17]).

Due to the expansive nature of the civil infrastructure, retrofitting or upgrading the existing infrastructure with appropriate sensors, actuators and a (wireless) communication network a solar powered network is appropriate (see for example Figure 1). A level of redundancy in sensor and actuator hardware is ideally required to ensure continued operation under inevitable field failure conditions.

Figure 1 illustrates typical TCC™ hardware, based on the Rubicon FlumeGate™ which acts as both a sensor (for both flow over the gate and water levels on both sides of the gate) as well as a (zero leak) flow regulator. The system is solar powered. A radio network provides communication connectivity between all the units and to a base station, where all the data are collected on a typical report by exception basis (SCADA). Precision manufacturing enables accurate water level sensing as well as accurate flow monitoring (verified to be within +/-2%), a

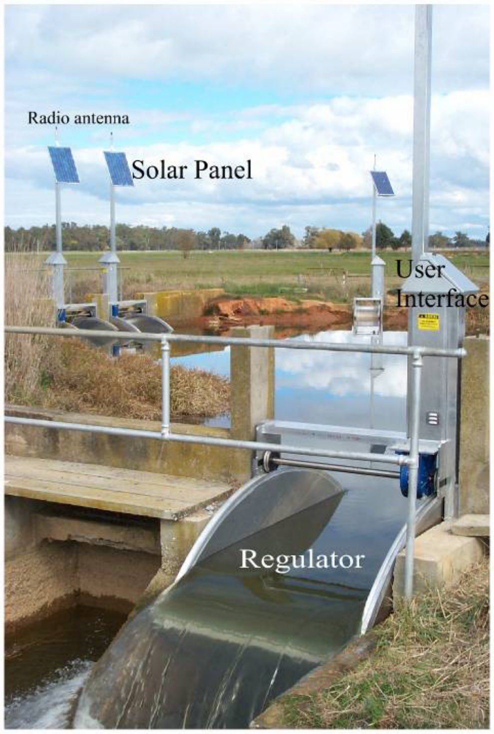

Figure 1. TCC™ hardware in Victoria, Australia

degree of redundancy can be catered for at the level of each structure or at a system design level. This enables a dynamic water balance over the channel network.

As to the spatial density of sensors, and the sampling time to monitor the variables Shannon's sampling criterion applies. Due to the dynamic relations between water flow, gate positions, and water levels, there is inherent dynamical relationship between the spatial and temporal sampling (also implying a level of redundancy). Reporting and data storage are more economically serviced using event or rule based sampling or reporting by exception. In typical Australian irrigation networks sampling rates in the order of minutes at the regulators suffices. Gate/measurement structures should "sample" the canals/rivers at 1 to 10 km resolution to achieve reasonable levels of data for modeling, control and management. Ideally, all variables are stored in a Geo-spatial Information System data base, and linked into the information systems that support the business side of the operation of the irrigation district.

Besides supply monitoring, water usage should also be monitored. (Irrigation losses are typically equally split between distribution and on-farm, indicating that significant gains can be made in on-farm efficiency as well.) Weather station information, soil moisture condition as well as crop stress can be established using a distributed on-farm sensor network. A Zigbee™ based network based on say NICTOR™ (trade mark of NICTA) provides one such solution that we are exploring in Victoria, in the context of dairy, horticulture and viticulture. (See Figure 2.) These data can be gathered to form a true operational picture of the entire irrigation district, enabling forward planning from the farm level to the entire district.

The overall objective is that an information infrastructure as suggested can support through automation and in conjunction with a water market, improved water efficiency and economic gains across an entire irrigation district. Significant economic gains, and a overall water efficiency of 75% are feasible. The cost to realize these savings is minor compared to water buy back schemes, or changing the open channel infrastructure into a piped network.

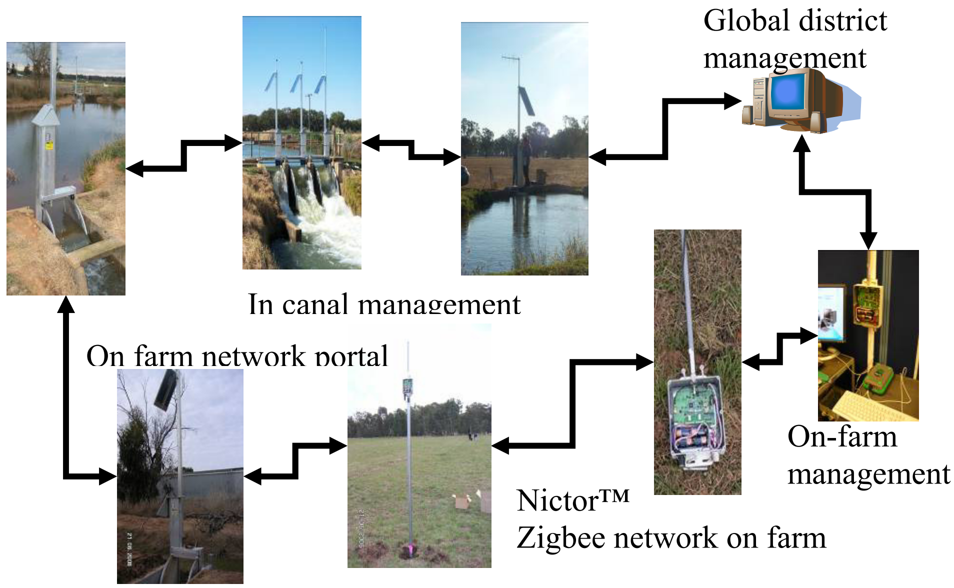

Figure 2: Water managed from "plant-to-reservoir". An information feedback loop in support of sustainable water management (pilot project in Victoria)

WATER INFORMATION NETWORK IMPLEMENTATION ISSUES

One of the great benefits of real time data is the potential to derive a dynamic, quantitatively correct model for the overall water system across the entire irrigation district (see [8,11]). Such a model underpins TCC™ in particular, but more generally any automation of objectives such as water efficiency and water level regulation whilst meeting demand as scheduled. The models also enable scenario simulation and decision support, and can be used for training.

The channel water balance allows one to identify leaks, excessive seepage and evaporation losses, which can be used to inform infrastructure upgrades and maintenance schedules.

Furthermore, automation of channel operation all but eliminates the need for "ditch riders" reducing the CO_2 footprint of the operations as well as alleviating occupational health concerns associated with manual operations of regulators. Automation of on-farm outlets provides similarly life style benefits for the farmer, but more importantly assists demand management and can underpin a better exploitation of the farm resources, and of course it links naturally into billing systems and water trading markets.

Integration of the supply management network with on-farm information networks, and more particularly crop monitoring, open the way to manage water distribution in feedback to crop requirements. Linking the information thus derived with an overall GIS data base would allow long term economic planning of the district, and enable a truly sustainable exploitation of the limited water resource such that the economic return of the available water is maximized within the constraints imposed by the physical infrastructure (reservoirs, canals, etc).

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