AGE OF INTELLIGENT METERING AND BIG DATA: HYDROINFORMATICS CHALLENGES AND OPPORTUNITIES

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We are at the dawn of a new era of widespread intelligent water metering delivering live consumption data to utilities and consumers in developed nations. As with most new technologies, intelligent metering will follow a type of hype cycle, where initial excitement and great expectation on its benefits is weighed down by disappointment and disillusionment from early adoptions and then strategic enlightenment will prevail and ultimately productive strategic implementation. Fortunately, the conservative nature of the water industry and the challenges of intelligent metering implementation have meant that the excitement never reached fever pitch and the sensible path to strategic enlightenment is being progressed, albeit very slowly. While the large multi-national metering and software companies have created a range of products and software systems for utilities to automatically collect, store and present reports on customer and citywide water consumption data, a plethora of informatics challenges urgently need to be addressed by researchers, engineers, planners and computer scientists to yield the numerous claimed urban water planning, engineering and management opportunities that can be extracted from this big data revolution. If the call to arms to address such challenges can be realised, significant opportunities will surface including water loss reductions, real-time design optimisation of water networks, live online water use tracking and billing, heightened customer satisfaction with the water utility sector, to name a few.

Introduction

A range of external factors have placed an increasing onus on water utilities to adopt more sustainable approaches to urban water management as the era of readily accessible and inexpensive water fades. Covering costs, monitoring non-revenue water and meeting customer demands for equity in billing in the face of rising water prices are some of the core challenges. Recognising that intelligent metering has the potential to revolutionise current utility operations and customer engagement approaches, this paper provides a summary of the key informatics challenges for researchers and industry practitioners to ensure that this technology fosters enhanced urban water management.

To date, roll-outs of intelligent metering have been driven by the desire to reduce manual readings, increase data on time of use, leakage management, and end-use measurement (e.g.

shower, toilet, etc.). Technology development in the water sector generally lags that seen in the electricity sector. In the coming decade, the deployment of intelligent water metering will transition from being predominantly pilot or trial studies to mainstream citywide implementation. Citywide intelligent metering implementations have the potential to stream gigabytes of time stamped water use and other associated information (e.g. water temperature, pressure, quality) from pipe networks right down to the individual water use appliances (e.g. washing machine) and fixtures (e.g. tap). Such datasets are powerful for a range of water planning, engineering and customer response decisions but only if processed, refined and reported in a way that is more intuitive and informative than traditional approaches.

This paper firstly provides a brief overview of intelligent metering and some of the key drivers and barriers to its widespread implementation. A more focused discussion on the benefits that can be derived from intelligent metering and the hydroinformatics challenges is then provided.

What Makes Water Metering Systems Intelligent?

The terms "intelligent" and "smart" metering are often indiscriminately associated with some combination of technology that is in some way superior to conventional metering. This inherent ambiguity is, however, indicative of the plethora of technological configurations intelligent metering covers, and its relevance to both the energy and water sectors. For example, automated meter reading systems (AMR) are often sold as intelligent metering systems, but they merely serve as a better way to collect customer water use data and rarely better inform utility operator or customer functions. Put simply, an intelligent metering system, should at a minimum, enable remote reading of water flow (consumption) and other optional data (e.g. water quality, pressure, etc.) at a resolution which improves current operational and customer decision making (e.g. collected in litre increments at least hourly), include accessible and user-friendly data registries of collected data, and autonomously produce readily accessible and useful reports for a range of purposes.

This latter requirement is really the core component of an intelligent metering system; big data alone without effective and efficient data mining methods and informatics algorithms to achieve enhanced decision making is really not that intelligent at all and will actually bog down water utility operations.

"Hydroinformatics is the key to unlock the benefits of the intelligent metering and big data revolution"

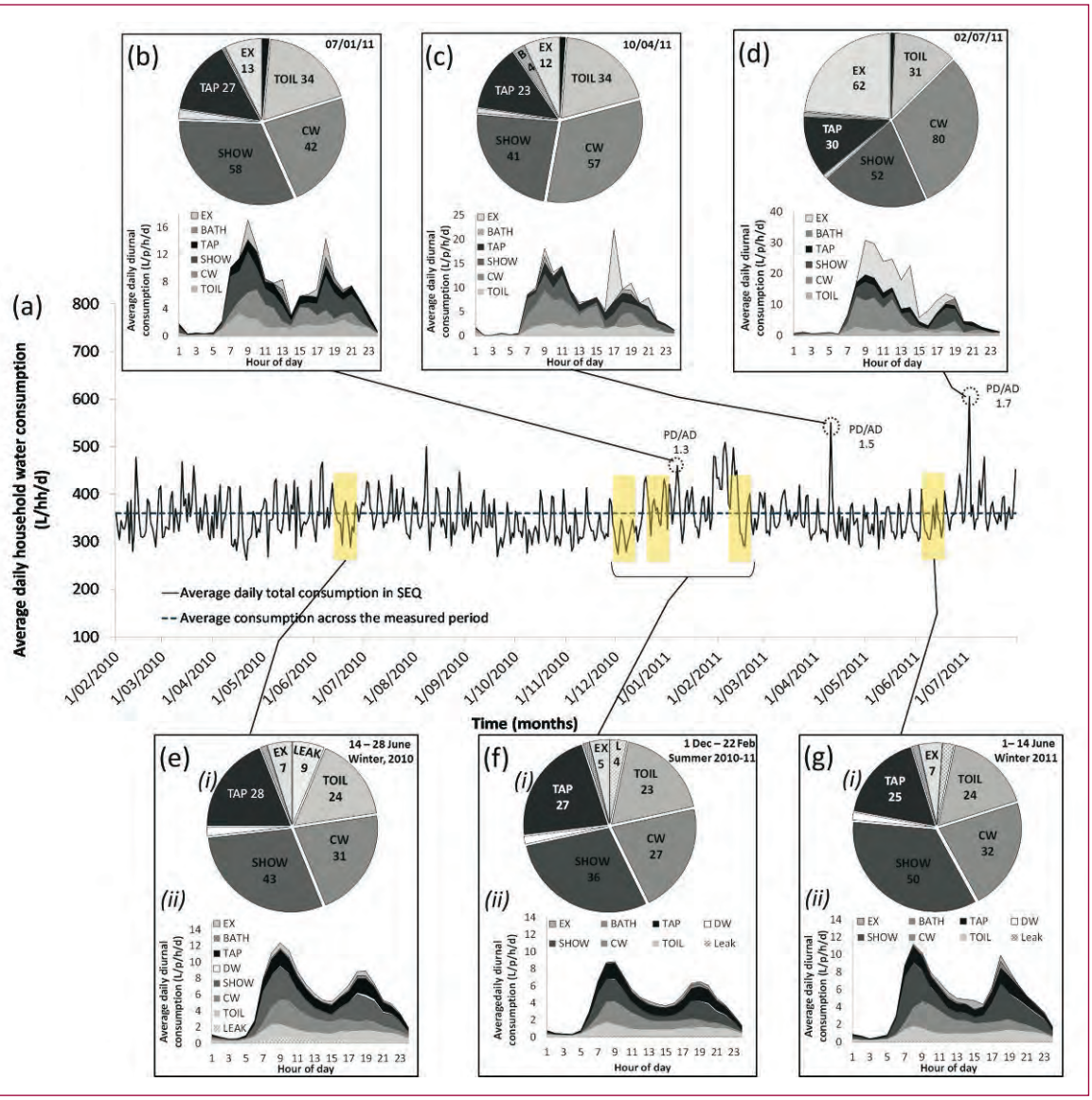

Figure 1: Example of how intelligent metering data can aid better understanding of daily diurnal demand patterns and peak demand (Beal and Stewart, 2013)

Drivers of Intelligent Water Metering

The diffusion of intelligent water metering into the urban setting has been slower than that of electricity. However, the cost for intelligent water meters has recently reduced to below USD100, thereby creating prospects for much wider deployment. Internationally, large scale deployments are rare (e.g. New York). Consequently, the drivers for intelligent water metering are not yet fully articulated, and nor is the cost-benefit proposition for intelligent water metering understood. To date, drivers for deployment include:

- Better understanding of time-of-day residential and commercial consumption to inform enhanced water supply design and management functions;
- More accurate accounting of water supply;
- Increasing water end-use or micro-component insights into consumption;
- Identifying and rapidly rectifying water losses in distribution networks and within customer connections (e.g. rapid toilet leak identification);
- Exploring the potential for alternative water pricing structures that are cost reflective;
- Seeking to enhance customer satisfaction with water utilities through providing enhanced information-based services (e.g. water bill budgets, leak alerts, etc.); and
- Seeking behaviour change in consumers through in-home displays, web-portals and smart phone applications.

Barriers to Intelligent Water Metering

To ensure that intelligent metering makes a positive contribution towards sustainable urban water management, a number of factors must be considered (Boyle et al. 2013). Handling big volumes of data generated by intelligent metering is a critical challenge, and could potentially revolutionise the way utilities operate. Further work to understand the implications of this change are needed. Additionally, more focus ought to be directed to customer needs. Given that the urban water sector is still largely within the government or quasi-government domain and enjoys monopoly status, the focus on customer satisfaction has been poor when compared with other privatised utility sectors such as telecommunications. Even the concept of harnessing basic information technologies such as the humble web site to convey simple water use and billing information is a foreign concept to many water utilities.

"Intelligent metering implementations are a process re-engineering exercise and not a technology adoption exercise"

However, implementing change with a poor understanding of customer needs has the potential for customer backlash, which has occurred in the more progressive electricity industry. Certain interest groups are strongly against intelligent metering, citing issues such as new pricing structures, security, health impacts from data transmissions, service interruptions and privacy. Giurco et al. (2010) discussed in detail the impact of collecting, collecting and communicating detailed water-use information on householder privacy. Issues with the management of data will arise if knowledge from intelligent systems is not properly and effectively managed by the utility. Thus, new skill sets for utility employees, including meta-data handling, information management and customer engagement is required when implementing intelligent systems. Utilities that choose not to acquire such skill sets, and outsource associated IT tasks, can incur the risk of technology vendors that propose off-the-shelf solutions that are ill-suited. The outsourcing option could also result in telecommunication companies or internet providers, already proficient in managing data and customer needs, to take on the management of water utility data. Therefore there is a very real need for utilities to adapt to the intelligent meter and 'big data' age, and lead the implementation effort based on theirs and their customers' needs. The future of the water utility will be data rich, hence water utilities need to adapt.

"Intelligent metering uptake is slow due to a limited focus on the back end data mining and analytics functionality as well as front end user orientation"

Still Unfulfilled Benefits of Intelligent Metering

The benefits of intelligent metering have been declared at many conferences by the growing hoard of companies seeking to be the global leader of this burgeoning industry. However, while 'product' is ready many of the potential benefits of intelligent metering systems have been unfulfilled due to the lack of focus on the necessary data mining and analytics functionality required for re-engineering the way the water utility sector goes about its business. Many of the unfulfilled benefits of intelligent metering include:

Better citywide urban water planning: intelligent metering enables better understanding of the water consumption patterns of a city's various residential, commercial and industrial customers and will aid urban water planners to better understand consumption trends and extract greater efficiencies from the present system.

Near real-time water distribution network analysis: Accurate and up-to-date demand data collected at a high resolution (Figure 1) is essential to ensure that future mains water supply networks reflects current usage patterns and are designed efficiently from an engineering, environmental and economic perspective (Beal and Stewart 2012).

Targeted water demand management: The prevalent reactionary policies to reduce water demand in supply crisis highlights the need for more detailed information at the "coalface". The use of intelligent metering and subsequent datasets could significantly improve decision making in relation to water demand management strategies.

Evidence-based water demand forecasting: Total and disaggregated water consumption data will also allow water businesses to monitor the effect of scarcity pricing or restriction regimes on water consumption in near real-time, and also monitor rebound trends following the removal of these strategies.

Proactive water loss management: A real-time monitoring system would also enable water utilities to intervene as soon as an exception alarm is raised (Britton et al. 2013).

Targeted demand efficiency: Regular monitoring of end-use consumption data provides the ability to immediately quantify the effect of targeted water efficiency programs on their intended water end-use(s) (e.g. can instantly establish savings from a washing machine rebate program implemented in a city).

Addressing water-related energy demand: data from intelligent water metering systems coupled with energy specifications for water supply products and fixtures (e.g. pumps, water heating systems, etc.) enables unpacking of water-energy nexus implications.

Evidence-based economic assessments: Intelligent metering and water end-use data

provides opportunities for detailed financial analyses on the cost and water saving benefits of implemented water supply programs, ultimately driving a true least cost planning agenda.

Cost reflective urban water tariff reform: Intelligent meters can also inform the development of different tariff systems (e.g. scarcity pricing) to influence consumption behaviour. While there are many fears related to tariff reform, it potentially has strong advantages for reducing consumption in water scarcity periods, peak network periods, etc. thereby reducing the average cost of water supply for the entire customer base.

Heightened customer satisfaction: The present customer water information and billing arrangements are vastly inadequate. An intelligent metering system provides the impetus for a new approach to knowledge transfer of water consumption data, directly to consumers via a range of communication platforms and in-house displays.

Hydroinformatic Experts - A Call to Arms!

Concurrent with technology diffusion must be the reform of water utility operations management and its people. Much of this reform revolves around thinking about how the introduction of new and abundant data from intelligent meters can bring about efficiencies and improvements to the day-to-day tasks of employees.

Expertise in the design and implementation of intelligent metering systems, including the collection, storage, processing and useful reporting of information to operators and customers, is the key skillset to yield all the benefits of the forthcoming intelligent metering revolution. This task is complex since it requires a new breed of multi-disciplined water professional that understands all the planning, engineering and customer service functions of a water utility but also has a strong understanding of the computer science discipline, including database design, pattern recognition, computer programming, to name a few. The road has not been paved for this new area, so hydroinformatics researchers have a role to tackle these new problems and carve out a path for budding practitioners.

Specific areas of required research attention from urban hydroinformatics researchers, engineers and planners, in order to extract the full benefits of intelligent metering include, but are not limited to, the following:

- Algorithms and decision support tools that utilise the intelligent water meter fleet in the network and individual premises to identify the location and type of leaks that are occurring in real-time based on their flow pattern (e.g. toilet leak in residential premise identified and owner alerted automatically by SMS to phone).
- Algorithms which can autonomously disaggregate residential and non-residential water consumption into end-use/micro-component categories (e.g. Nguyen et al. 2013) and provide this information back to customers and utilities in a useful manner.
- Near real-time integration of flow meter data from distribution pipes with individual customer flow meters to allow real time network modelling of pipe networks and transition engineers towards just-in-time augmentation decision making.
- Databases and associated algorithms that can extract useful water consumption information to customers (e.g. enables customers to compare their consumption with others in their suburb) and water utility operators (e.g. can instantly reveal the water savings of a showerhead retrofit program in their city).
- Full integration of water consumption and billing information systems to enable customers to follow their progress towards set water budgets and utilities to explore potential alternative tariff structures.

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