Edge mining for energy efficient IoT

Wilkins, R. , Brusey, J. , Gaura, E. , Allen, M. and Kemp, J.

Edge Mining for Energy Efficient IoT

Ross Wilkins, James Brusey, Elena Gaura, Mike Allen, John Kemp

Cogent Labs, Coventry University

Cogent Labs is a world-leading applied research centre at Coventry University, dedicated to analysis and development of sensing-based socio-technical systems. It has a dual focus: robust, deployable pervasive IoT sensing systems for real-life applications at scale; and effective packages for empowering users to maximise the benefits of those systems.

Since its inception in 2006, Cogent has quickly become an established world centre of excellence in Internet of Things (IoT). It has attracted several million pounds worth of funding across a wide range of high-impact projects, from sources including The EU, EPSRC, TSB, and a portfolio of direct industrial funding. High-profile partners have included Cambridge University, MIT, Meggitt PLC, Jaguar Land Rover and Orbit Heart of England Housing Association.

The group has world-leading expertise in application areas such as physiological measurement (posture; health stress risk prediction), buildings monitoring, and assistive technology (AT). It has made two important world first innovations: real-time on-body posture monitoring and movement analytics; and low-power, robust, unobtrusive home monitoring solutions at industrial scale (over 100 homes within 8 separate projects, with monitoring periods up to 3 years). Both applications are based on the underlying edge mining technology described below.

1 Edge mining

The ability to collect data about environments, equipment, people and activities has drastically increased over the past two decades, primarily due to advances in low power wireless computing and the ubiquity of smart phones. Pervasive low-power, smart embedded devices and RFID tags enable IoT applications, where smart objects sense the environment, react autonomously to physical events and trigger actions with or without human intervention [1]. Many IoT scenarios (smart cities, products, mobility, health and living) [2] are built using resource constrained devices that *sense* and *send* data wirelessly over limited bandwidth connections. Enabling IoT applications at scale hinges on advances in two key areas:

- *Cost*—the energy and infrastructural cost of powering sensors, communicating wirelessly, and storing the associated data; and

- *Analytics*—the provision of automatic interpretation of raw measurement data into information that is relevant, timely and actionable.

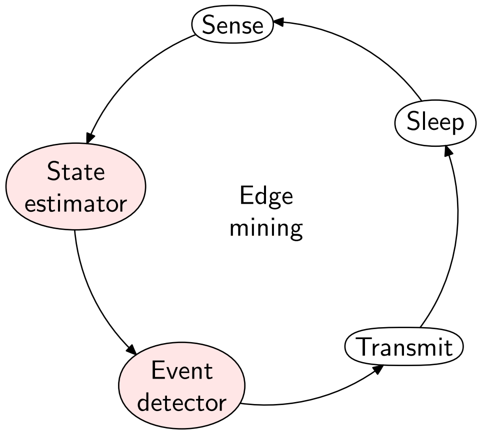

Figure 1: A summary of the edge mining process at the node.

Table 1: Comparing the performance of BN [3] with L-SIP [3] and SS (sense and send) for one year of temperature data.

	Transmissions	% of SS	RMSE in band %	Lifetime increase
SS	102236	100%	–	–
L-SIP	2900±700	2.8%	0.9±0.2	×13
BN	15±6.5	0.02%	12±4	×14

We propose that mechanisms for moving intelligence and analytic capabilities into the network will result in better utilisation of the scarce energy resources at IoT nodes, with less transmissions leading to less network load and a higher data yield. We term these mechanisms *edge mining,* or data mining that takes place on wireless, battery-powered, smart sensing devices that sit at the edge of the IoT network [3]. When edge mining algorithms are employed to destructively transform data into narrowly-specified information, the number of potential ways this information may be further mined is reduced, thus improving privacy.

We define edge mining (or data mining at the edge) to be *processing of sensory data near or at the point at which it is sensed, in order to convert it from a raw signal to contextually relevant information*. Figure 1 illustrates our view of edge mining as a process that runs on individual sensor nodes.

Results for various edge mining algorithms (e.g., BN, L-SIP [3]) show the benefits of the edge mining approach. Specifically, Table 1 compares the message reduction between sense and send (SS), L-SIP (which uses linear prediction and the raw signal can be reconstructed) and BN (which sends only summaries and the signal is not reconstructable) for one year's worth of temperature data taken from a house monitoring application. L-SIP reduces the number of transmissions by 97.2% (36-fold) and BN reduces the number of transmissions by 99.98% (5000-fold). Various overheads means that although BN reduces transmissions greatly over L-SIP, only a small additional increase in lifetime is achieved.

2 Response to guiding questions

2.1 Technology trends

Practical feasibility of IoT applications often hinges on battery powered devices (mobile phones, wireless sensors) that have limited battery life and may be inconvenient to frequently recharge or replace. A coming trend is an increasing emphasis on low-power approaches that substantially reduce power consumption through less sensing or less wireless transmission.

Central to IoT is the analysis of the resulting information thus leading to rising popularity and importance of data science and the integration of machine learning into everyday life. This leads to potential threats to our privacy due to easily availability of information about preferences, habits, and lifestyle choices. Edge mining provides a way to reestablish privacy.

Prior work on IoT has focused on data gathering. A rising trend is towards actuation and control, such as the consumer products, Nest and Hive.

2.2 Obstacles for innovation

A key obstacle to the use of IoT in a wider range of applications is the vertically structured and proprietary architectures used to connect the world of things to the Internet. Open architectures and accepted standards based on well-proven but innovative algorithms and approaches are needed.

Currently IoT prototypes based on a single central server architecture. However, when these devices are scaled up, a distributed architecture may be more suitable to manage these systems. Furthermore, data reduction techniques are needed to avoid vastly increasing network traffic and storage requirements as the scale up occurs.

A connected issue is that of battery life for remotely deployed, IoT nodes. New business models will be needed to exploit IoT technology fully. Such businesses will create wealth from the margin between the value of information IoT provides and the cost of obtaining that information. Thus, a key obstacle is the efficient and low-cost extraction of information from real world systems, which implies low-energy (long battery life), low-cost, and robust devices.

Not all information is equally important. Being able to decide as early as possible in the collection process avoids waste and is the central theme of edge mining algorithms.

2.3 Platforms

While physical devices are important, software platforms will play a key role. Specifically, such platforms should be sufficiently open to enable support of innovative algorithms such as the edge mining algorithms mentioned in this paper.

Furthermore, both software and hardware platforms need to be extensively tested in real-life deployments. Although some deployment work has been performed, much development is done in simulation. Practical experience is essential to building robust platforms.

3 Vision

We believe that edge mining is an essential component of a larger open framework for IoT systems, since:

- it saves energy on the node
- it reduces network traffic
- it reduces storage
- in some cases it can significantly improve privacy,
- it is well-suited to actuation and control.

References

[1] L. Atzori, A. Iera, and G. Morabito, "The internet of things: A survey," *Computer Networks*, vol. 54, no. 15, pp. 2787–2805, 2010. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1389128610001568

[2] O. Vermesan, P. Friess, P. Guillemin, S. Gusmeroli, H. Sundmaeker, A. Bassi, I. S. Jubert, M. Mazura, M. Harrison, M. Eisenhauer, and P. Doody, "Internet of things strategic research roadmap," Online: http://www.internet-of-things-research.eu/pdf/IoT_Cluster_Strategic_Research_Agenda_2011.pdf, 2011, cluster of European Research Projects on the Internet of Things.

[3] E. Gaura, J. Brusey, M. Allen, R. Wilkins, D. Goldsmith, and R. Rednic, "Edge mining the internet of things," *Sensors Journal, IEEE*, vol. 13, no. 10, pp. 3816–3825, 2013. [Online]. Available: http://dx.doi.org/10.1109/JSEN.2013.2266895