ARCHITECTURE AND FIELD TEST OF A RESTFUL WEB SERVICE FOR THE OPTIMISATION OF SPACE HEATING IN A COMMERCIAL OFFICE

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ABSTRACT

The optimal operation of many building services (including HVAC) requires computational resources that are not necessarily available in commercial building management systems (BMS). Having this computational power available in a dedicated data center will ease the deployment of these algorithms, but raises several issues having mostly to do with getting the data out of the BMS and back to it.

In this work we report on the architecture and field tests of Neurobat Online (NOL), a RESTful web service that implements the Neurobat heating control algorithm developed at EPFL. It has been controlling the space heating of a commercial building in Winterthur (Switzerland) for the second half of the 2014–2015 heating season. The original controller operated during the first half of the same heating season. By comparing the energy performance with and without NOL we derive estimates for the relative energy savings that such a system can achieve.

INTRODUCTION

In spite of the availability of advanced heating control systems, most commercial buildings in the developed world are still managed using the same principles as residential homes, e.g. by weather-compensated controllers. These controllers pump a heating fluid heated to a certain temperature whose setpoint is almost always a simple, monotonous function of the outdoor temperature. This scheme, while simple to setup and configure to ensure that the users are warm enough, tends to ignore the physics of the building and, more critically, makes no provision for the inclusion of any weather forecast.

However, more and more buildings are being equipped with building management systems (BMS) that can, through a graphical interface, be configured by the facility manager to obtain values for this flow temperature setpoint from other sources than the heating curve. In particular, it has become possible to provide this value to the BMS either directly over the internet or indirectly, through the building automation and control system used in that building.

Controlling the building services of a building over the internet appears to be a relatively unexplored topic in the academic literature. For example, [1] describes a set of web services for the “smart home”, i.e. a central computer in the house connected to sensors, actuators and HVAC systems, and that exposes a set of web services to the public internet. Through these services, the users can monitor their energy consumption or set their preferred setpoints, while utility companies can facilitate demand response or sell excess energy back to the grid when it is economical to do so. The same system has been extended in [2] to improve the demand response aspect and the energy management algorithms.

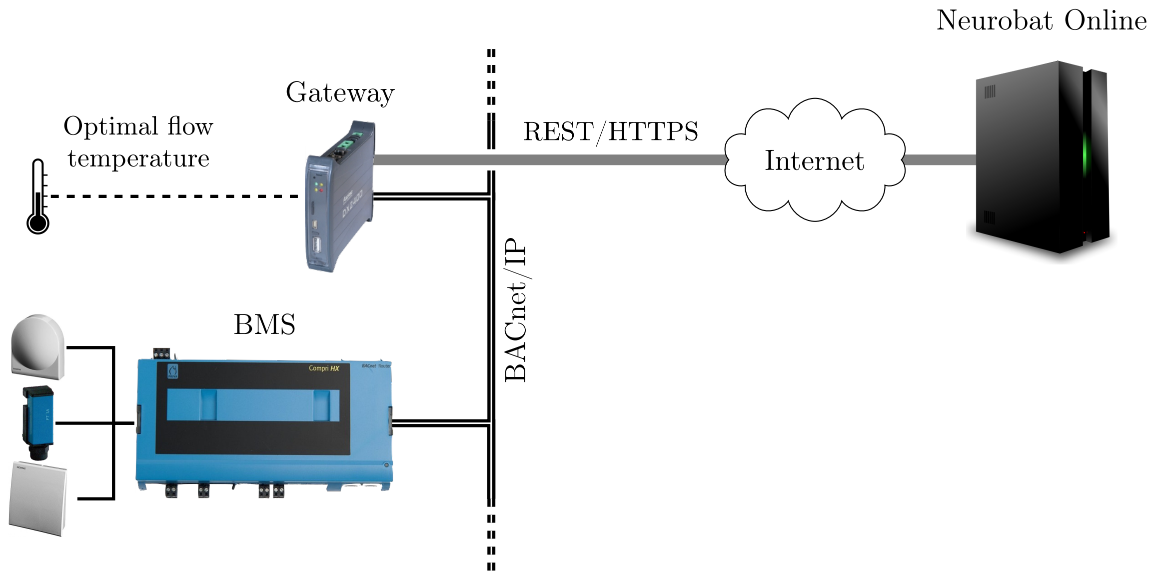

Figure 1: Schematic deployment of the Neurobat Online (NOL) system. The BMS is connected to sensors and actuators and makes them available on the local BACnet network. The NOL gateway is connected to the same network and exposes a so-called `AnalogValue` *BACnet object representing the computed optimal flow temperature. The gateway communicates via the public internet to the NOL server, posting the sensor values and getting the computed flow temperature back.*

Apart from these two examples, we were unable to find other examples of field tests of remotely controlled buildings.

The NEUROBAT technology, described in [3] and references therein, is an adaptive, model-predictive controller for optimising the space heating in buildings. We have extended this technology to handle the optimisation of space heating in commercial buildings, and implemented it as a REST[1] web service. We have installed this system on a commercial building in Winterthur owned (and occupied) by a major facility management firm. In this work we will detail the factors that justify the architectural choices we have made, describe the installation, and report on the results.

SYSTEM ARCHITECTURE

Several assumptions have guided our architectural choices in this project. First, we assume that the buiding is already equipped with the necessary sensors and actuators, and that a central BMS aggregates the data collected from the sensors. We also assume that the data from these sensors is published on a standard bus, BACnet/IP in this case. We assume that we can install a small device on that network, able to read the sensor values published on the bus and able to publish values for the optimal flow temperature back to the bus. This device is also connected to the public internet and serves as a gateway, translating between the local building bus system and a proprietary API that we have developed for this project. The setup is shown schematically in Fig. 1.

We believe that this setup achieves all of the non-functional requirements that can be asked by a customer:

[1] REpresentational State Transfer, a set of guidelines for designing web services.

Security: the communication from the gateway to NOL uses SSL, with HTTP Basic Authentication. This ensures that no eavesdropping is possible, and that two NOL customers cannot intercept each other's data.

Reliability: the gateway transmits sensor data at intervals that are shorter than theoretically necessary, to minimise the probability that any data should be lost due to connectivity issues.

Fault-tolerance: BACnet objects support a status flag that can indicate faults. By checking this flag, the BMS can fall back to its heating curve if a fault is reported.

Simplicity: no connection is initiated from NOL to the local system. All communication is initiated by the gateway over TCP/IP, port 443, which is usually open for arbitrary outgoing traffic in corporate firewalls.

Resiliency: the network connectivity, usually provided by the customer, is a single point of failure. NOL will therefore transmit to the gateway not only the optimal flow temperature for the next timestep, but for the next 6 hours. These values are cached by the gateway to be communicated to the building management system in case the NOL server should not be reachable. An alert is also generated notifying the operator that no message has been received from the installation.

In RESTful web services, every "interesting" piece of information exposed by a server (user accounts, pictures, blog posts, etc) is called a *resource* and is mapped to a URL. All the operations that the server can do are done by sending one of the standard HTTP verbs (`GET`, `POST`, etc) to a resource, possibly with a payload. REST recommends that the HTTP verbs follow several semantic conventions. For example, `GET` operations should return a representation of the resource (typically, a web page) and be safe and idempotent. `POST` is usually sent to a resource representing a collection of other resources, and appends a new element to that collection.

We have tried to follow that convention with NOL. Every NOL site is mapped to the `/sites/######` URL, where `######` is a unique identifier for that site during site creation. A new site can be created by `POST`ing to `/sites`. New sensor data can be `POST`ed to `/sites/######/sensors`. The optimal setpoint for the flow temperature is obtained by performing a `GET` request. We have found that strictly adhering to REST conventions results in a server API that is simpler, easier to document, and easier to test.

DEPLOYMENT

The left side of Fig. 2 shows the three-floor commercial office building in Winterthur where the system has been installed. The building is split in two heating zones. A heating schedule is in effect, applying typical office hours and reduced heating in the evening, nights, and the weekend.

The right side of Fig. 2 shows the rack where the existing BMS, a CompriHX system from Priva, has been installed. The gateway sits at the top of the rack, and is connected to the same LAN as the BMS. All sensors and actuators are available as BACnet objects, and the optimal flow temperature computed by NOL is published by the local gateway as two BACnet `AnalogValue` objects, one per zone. These objects are regularly read by the BMS, whose control algorithms adjust the mixing valves in order to keep the flow temperature as close as possible to these setpoints.

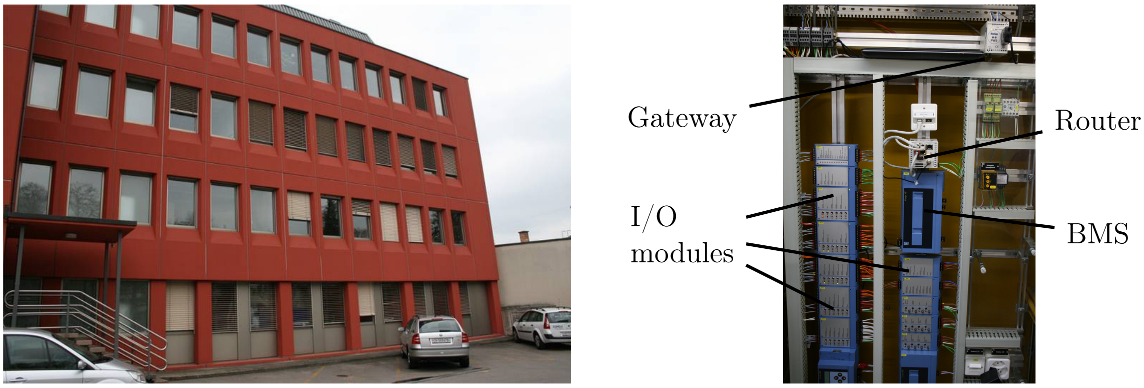

Figure 2: Left: the building in Winterthur. Right: the building management system (BMS), its I/O modules, the industrial router and the local gateway interfacing between the local bus and the NOL server.

The BMS operator can also revert to a standard heating-curve based system, using a setpoint for the flow temperature calculated from the outdoor temperature instead of the value provided by NOL.

The system ran with the standard heating-curve from 29 October 2014 to 8 February 2015, and with NOL since then.

RESULTS

In Fig. 3 we plot the indoor temperature, the outdoor temperature, the solar irradiance and the flow temperature.

For each day of the heating season, we compute the average outdoor temperature and the total space heating energy consumed by each of the two heating circuits. We also know which, of the reference or the NOL controller, was running on each day. Plotting the daily space heating against the average outdoor temperature for that day yields the so-called *energy signature* of the building, i. e. the extra heat required for each extra degree of cold. These signatures are shown in Fig. 4.

These plots show that the linear relationship between outdoor temperature and space heating energy holds very well with the reference controller, with about 16.4 $\text{kWh.d}^{-1}.\text{K}^{-1}$ for zone 1 and 18.3 $\text{kWh.d}^{-1}.\text{K}^{-1}$ for zone 2. The linear fit is not as good with the NOL controller, which is explained by the presence of days during which *no* heating was applied. These days correspond to weekends, during which the indoor temperature was allowed to naturally fall to the reduced temperature setpoint. The heating was then restarted at the time when doing so was the most energy-efficient.

The NOL controller is thus much better at handling night- and weekend-setback temperatures than the reference controller, which makes a direct comparison of their energy signatures impossible. The reference controller will merely shift its heating curve by a constant offset, while NOL will shut the heating completely off. In spite of this, the difference in slopes between both signatures allows a careful, conservative estimate of about 30–40% energy savings.

Finally we show in Fig. 5 the distribution of the indoor temperature during normal office hours for each zone and each controller. The reference line shows the normal indoor

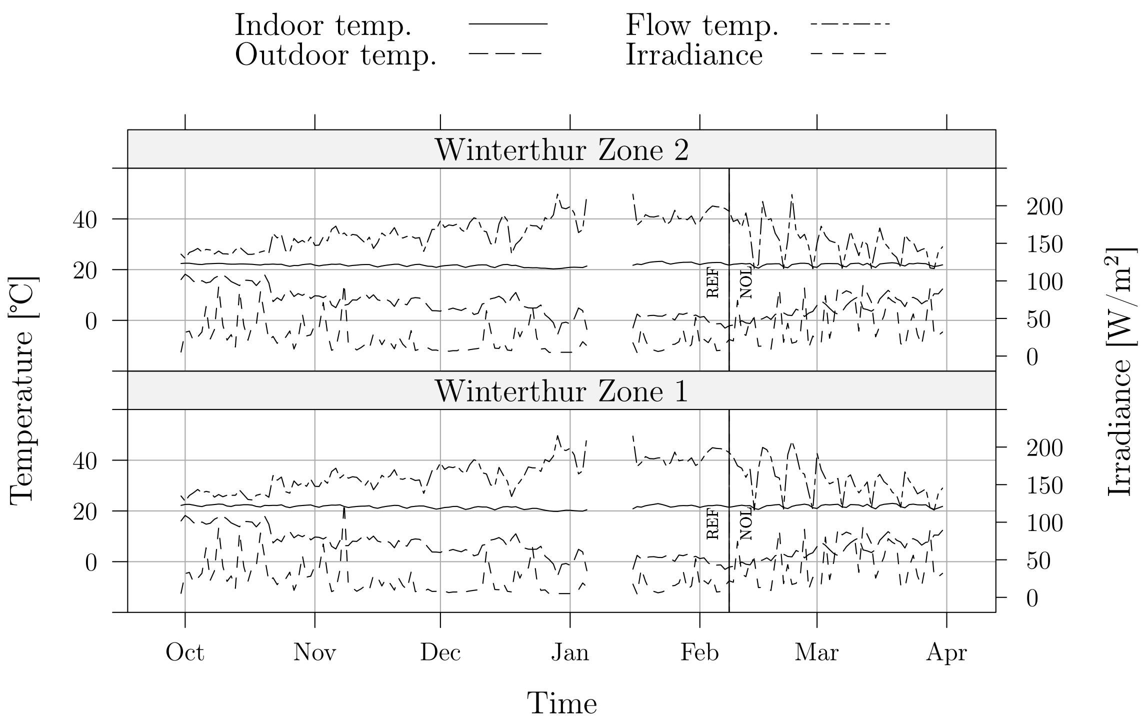

Figure 3: Daily averages of temperatures and solar irradiance measured on the Winterthur site. The vertical line indicates when the controller was switched from the reference controller to NOL. No updates to the BACnet objects were received by the BMS for a few days in January, hence the missing values. Notice the clear tendency by NOL to shut the heating off during weekends.

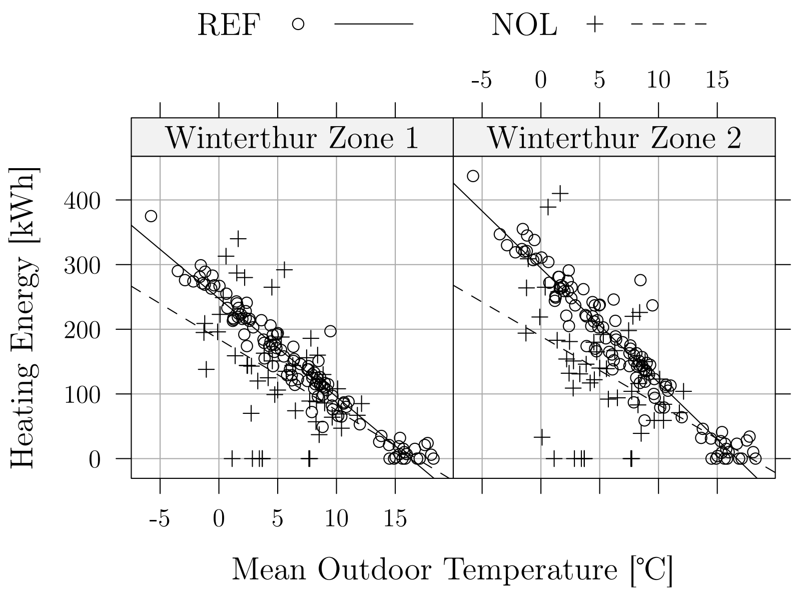

Figure 4: Daily space heating energy against average outdoor temperature. Each point represents one day of measurements. Different symbols are used for the reference controller and for the NOL controller. Each pane shows one of the two heating circuits. A linear regression line is added to each controller.

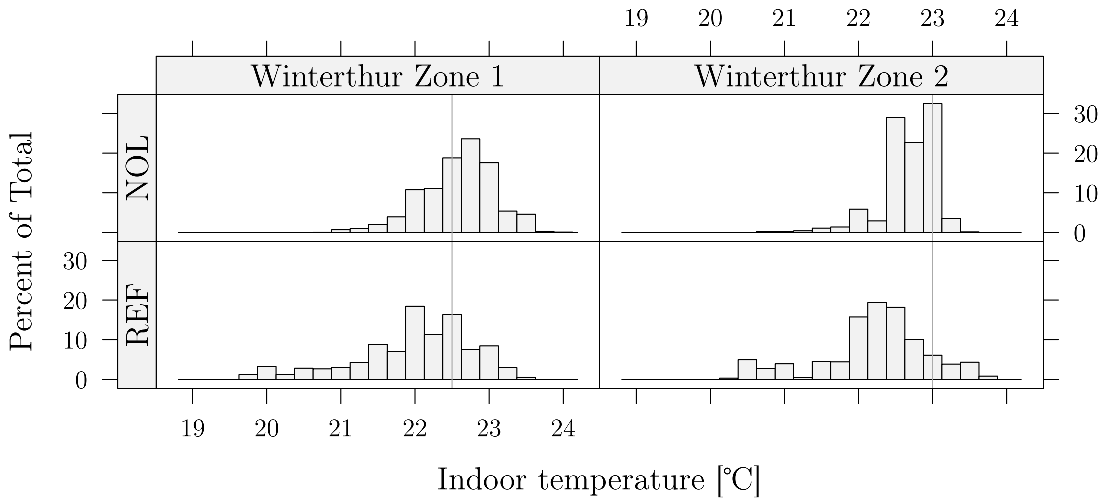

Figure 5: Indoor temperature distribution with both controllers and both heating circuits. These histograms include only samples taken during normal offices hours, and excludes the weekend. A reference line shows the temperature setpoint chosen by the user.

temperature setpoint chosen by the user. This plot shows that the energy savings achieved by the NOL controller have not compromised the indoor comfort, quite the contrary.

CONCLUSION

We have deployed and tested Neurobat Online (NOL), a RESTful web service for the optimisation of space heating in office buildings. We have described the principles that guided its architecture, described its deployment on a commercial building in Winterthur, and found energy savings of the order of 30–40%. These energy savings have not compromised the comfort of the occupants of the building; indeed, the comfort has been improved.

We believe that this demonstration has validated the principle of having a web service responsible for something as critical as the thermal comfort of office workers. We plan to pursue this project during the next heating season, by including other kinds of buildings and also by including building network protocols other than BACnet.

References

1. Khan, A. A. and Mouftah, H. T.: Web services for indoor energy management in a smart grid environment. *2011 IEEE 22nd International Symposium on Personal, Indoor and Mobile Radio Communications*, pages 1036–1040, 2011.
2. Khan, A. A. and Mouftah, H. T.: Energy optimization and energy management of home via web services in smart grid. In *2012 IEEE Electrical Power and Energy Conference*, pages 14–19, 2012.
3. Lindelöf, D., Afshari, H., Alisafaee, M., Biswas, J., Caban, M., Mocellin, X., and Viaene, J.: Field tests of an adaptive, model-predictive heating controller for residential buildings. *Energy and Buildings*, 99:292–302, 2015.