      Building Automation Use Cases and Requirements for Deterministic
                                Networking
                       draft-bas-usecase-detnet-00

Abstract

   This document describes Building Automation System (BAS) use cases
   and its requirements for deterministic networking.

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1. Introduction

   Building Automation System (BAS) is a system that manages various
   equipment and sensors in buildings (e.g., heating, cooling and
   ventilating) for improving residents' comfort, reduction of energy
   consumption and automatic responses in case of failure and emergency.
   For example, BAS measures temperature of a room by using various
   sensors and then controls the HVAC (Heating, Ventilating, and air
   Conditioning) system automatically to maintain the temperature level
   and minimize the energy consumption.

   There are typically two layers of network in a BAS. Upper one is
   called management network and the lower one is called field network.
   In management networks, an IP-based communication protocol is used
   while in field network, non-IP based communication protocols (a.k.a.,
   field protocol) are mainly used.

   There are many field protocols used in today's deployment in which
   some medium access control and physical layers protocols are
   standards-based and others are proprietary based. Therefore the BAS
   needs to have multiple MAC/PHY modules and interfaces to make use of
   multiple field protocols based devices. This situation not only
   makes BAS more expensive with large development cycle of multiple
   devices but also creates the issue of vendor lock-in with multiple
   types of management applications.

   The other issue with some of the existing field networks and
   protocols are security. When these protocols and network were
   developed, it was assumed that the field networks are isolated

physically from external networks and therefore the network and
protocol security was not a concern. However, in today's world many
BASes are managed remotely and is connected to shared IP networks and
it is also not uncommon that same IT infrastructure is used be it
office, home or in enterprise networks. Adding network and protocol
security to existing system is a non-trivial task.

This document first describes the BAS functionalities, its
architecture and current deployment models. Then we discuss the use
cases and field network requirements that need to be satisfied by
deterministic networking.

2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
"SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
document are to be interpreted as described in BCP 14, RFC 2119
[RFC2119].

3. Building Automation Systems

3.1. BAS Functionality

Building Automation System (BAS) is a system that manages various
devices in buildings automatically. BAS primarily performs the
following functions:

o Measures states of devices in a regular interval. For example,
   temperature or humidity or illuminance of rooms, on/off state of
   room lights, open/close state of doors, FAN speed, valve, running
   mode of HVAC, and its power consumption.

o Stores the measured data into a database (Note: The database keeps
   the data for several years).

o Provides the measured data for BAS operators for visualization.

o Generates alarms for abnormal state of devices (e.g., calling
   operator's cellular phone, sending an e-mail to operators and so
   on).

o Controls devices on demand.

o Controls devices with a pre-defined operation schedule (e.g., turn
   off room lights at 10:00 PM).

3.2. BAS Architecture

   A typical BAS architecture is described below in Figure 1. There are
   several elements in a BAS.
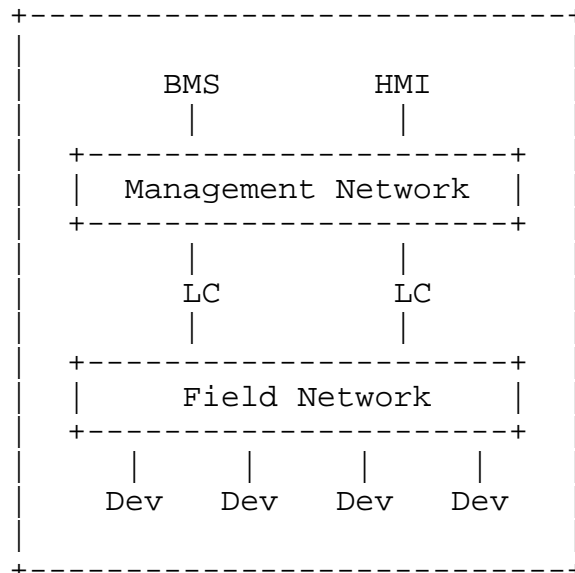
```
              +-------------------------------+
              |                               |
              |      BMS          HMI         |
              |       |            |          |
              |   +----------------------+    |
              |   |  Management Network  |    |
              |   +----------------------+    |
              |       |            |          |
              |       LC           LC         |
              |       |            |          |
              |   +----------------------+    |
              |   |     Field Network    |    |
              |   +----------------------+    |
              |    |    |     |     |         |
              |   Dev   Dev   Dev   Dev       |
              |                               |
              +-------------------------------+


              BMS := Building Management Server
              HMI := Human Machine Interface
              LC  := Local Controller
```

                    Figure 1: BAS architecture

   Human Machine Interface (HMI): It is commonly a computing platform
   (e.g., desktop PC) used by operators. Operators perform the
   following operations through HMI.

   o Monitoring devices: HMI displays measured device states. For
      example, latest device states, a history chart of states, a popup
      window with an alert message. Typically, the measured device
      states are stored in BMS (Building Management Server).

   o Controlling devices: HMI provides ability to control the devices.
      For example, turn on a room light, set a target temperature to
      HVAC. Several parameters (a target device, a control value,
      etc.), can be set by the operators which then HMI sends to a LC
      (Local Controller) via the management network.

   o Configuring an operational schedule: HMI provides scheduling
      capability through which operational schedule is defined. For
      example, schedule includes 1) a time to control, 2) a target
      device to control, and 3) a control value. A specific operational

example could be turn off all room lights in the building at 10:00
PM. This schedule is typically stored in BMS.

Building Management Server (BMS) collects device states from LCs
(Local Controllers) and stores it into a database. According to its
configuration, BMS executes the following operation automatically.

o BMS collects device states from LCs in a regular interval and then
   stores the information into a database.

o BMS sends control values to LCs according to a pre-configured
   schedule.

o BMS sends an alarm signal to operators if it detects abnormal
   devices states. For example, turning on a red lamp, calling
   operators' cellular phone, sending an e-mail to operators.

BMS and HMI communicate with Local Controllers (LCs) via IP-based
communication protocol standardized by BACnet/IP [bacnetip], KNX/IP
[knx]. These protocols are commonly called as management protocols.
LCs measure device states and provide the information to BMS or HMI.
These devices may include HVAC, FAN, doors, valves, lights, sensors
(e.g., temperature, humidity, and illuminance). LC can also set
control values to the devices. LC sometimes has additional
functions, for example, sending a device state to BMS or HMI if the
device state exceeds a certain threshold value, feedback control to a
device to keep the device state at a certain state. Typical example
of LC is a PLC (Programmable Logic Controller).

Each LC is connected with a different field network and communicates
with several tens or hundreds of devices via the field network.
Today there are many field protocols used in the field network.
Based on the type of field protocol used, LC interfaces and its
hardware/software could be different. Field protocols are currently
non-IP based in which some of them are standards-based (e.g., LonTalk
[lontalk], Modbus [modbus], Profibus [profibus], FL-net [flnet],) and
others are proprietary.

3.3. Deployment Model

An example BAS system deployment model for medium and large buildings
is depicted in Figure 2 below. In this case the physical layout of
the entire system spans across multiple floors in which there is
normally a monitoring room where the BAS management entities are
located. Each floor will have one or more LCs depending upon the
number of devices connected to the field network.

```
+----------------------------------------------------+
|                                          Floor 3   |
|      +----LC~~~~+~~~~~+~~~~~+                       |
|      |          |     |     |                       |
|      |         Dev   Dev   Dev                      |
|      |                                              |
|--- | |  -------------------------------------------|
|      |                                   Floor 2   |
|      +----LC~~~~+~~~~~+~~~~~+   Field Network       |
|      |          |     |     |                       |
|      |         Dev   Dev   Dev                      |
|      |                                              |
|--- | |  -------------------------------------------|
|      |                                   Floor 1   |
|      +----LC~~~~+~~~~~+~~~~~+   +------------------  |
|      |          |     |     |   | Monitoring Room   |
|      |         Dev   Dev   Dev  |                   |
|      |                          |   BMS    HMI      |
|      |   Management Network     |   |      |        |
|      +--------------------------------+-----+       |
|                                  |                  |
+----------------------------------------------------+
```
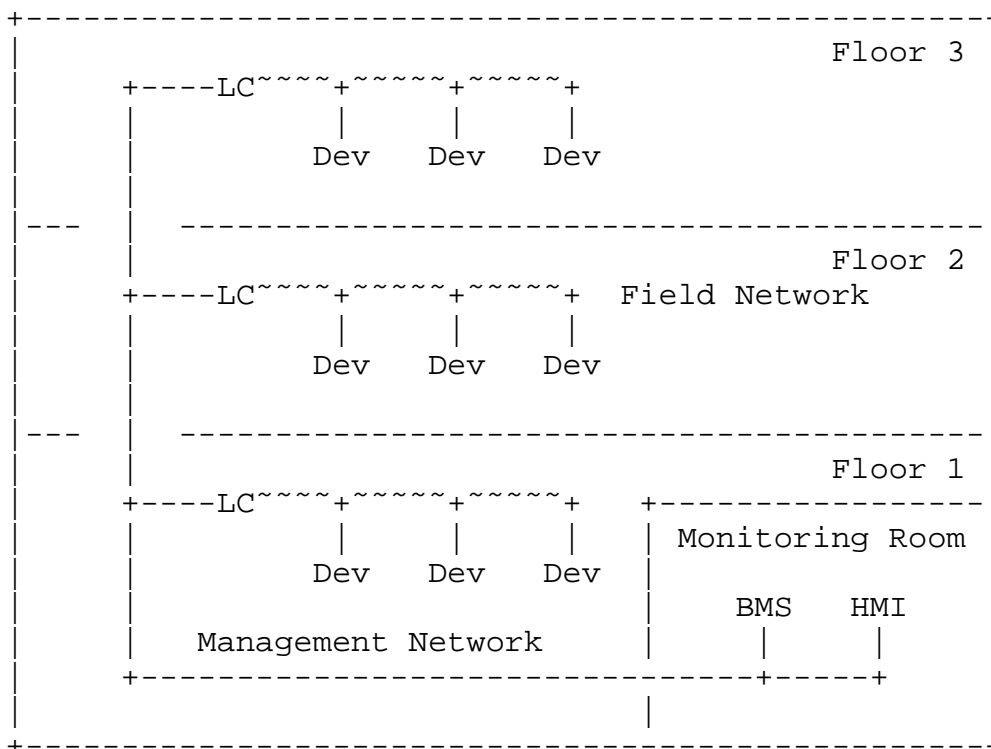
           Figure 2: Deployment model for Medium/Large Buildings

   Each LC is then connected to the monitoring room via the management
   network. In this scenario, the management functions are performed
   locally and reside within the building. In most cases, fast Ethernet
   (e.g. 100BASE-TX) is used for the management network. In the field
   network, variety of physical interfaces such as RS232C, and RS485 are
   used. Since management network is non-real time, Ethernet without
   quality of service is sufficient for today's deployment. However,
   the requirements are different for field networks when they are
   replaced by either Ethernet or any wireless technologies supporting
   real time requirements (Section 3.4).

   Figure 3 depicts a deployment model in which the management can be
   hosted remotely. This deployment is becoming popular for small
   office and residential buildings whereby having a standalone
   monitoring system is not a cost effective solution. In such
   scenario, multiple buildings are managed by a remote management
   monitoring system.

```
                                             +---------------+
                                             | Remote Center |
                                             |               |
                                             |  BMS     HMI  |
       +-----------------------------------+ |   |       |   |
       |                        Floor 2    | |   +---+---+   |
       |  +----LC~~~~+~~~~~+ Field Network| |       |       |
       |  |          |     |               | |    Router    |
       |  |         Dev   Dev              | +-------|-------+
       |  |                                |         |
       |--- |  -----------------------------|         |
       |  |                        Floor 1  |         |
       |  +----LC~~~~+~~~~~+               |         |
       |  |          |     |               |         |
       |  |         Dev   Dev              |         |
       |  |                                |         |
       |  |  Management Network            |    WAN  |
       |  +------------------------Router-------------+
       |  |                                |         |
       +-----------------------------------+
```
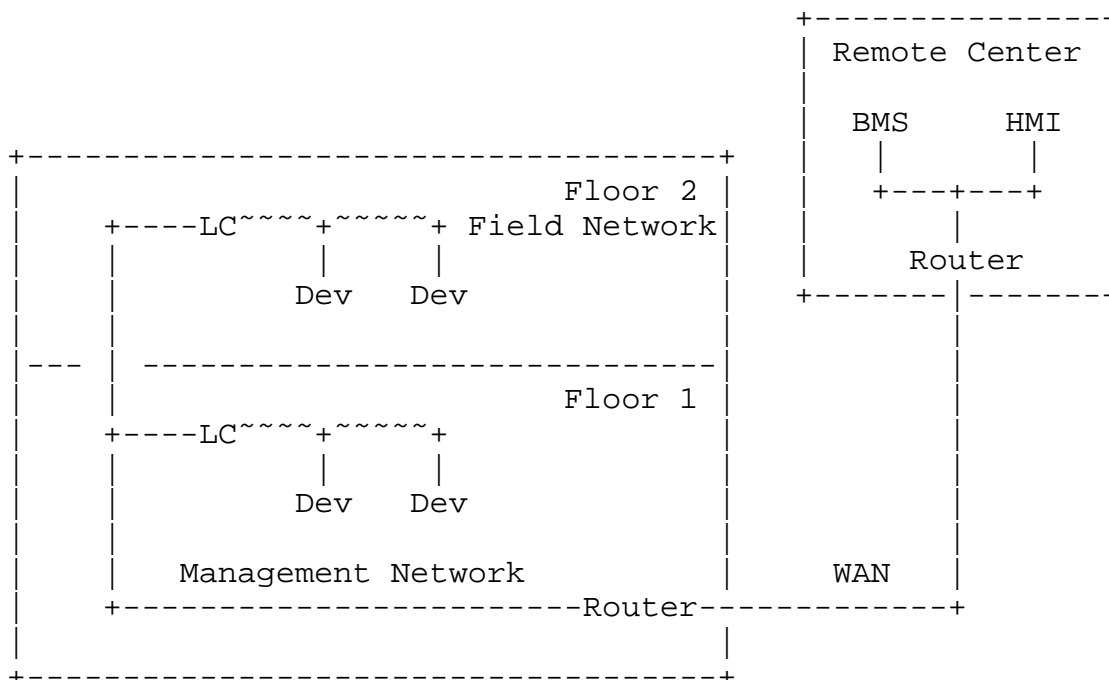
                Figure 3: Deployment model for Small Buildings

   In either case, interoperability today is only limited to the
   management network and its protocols. In existing deployment, there
   are limited interoperability opportunity in the field network due to
   its nature of non-IP-based design and requirements.

3.4. Use cases and Field Network Requirements

   In this section, we describe several use cases and corresponding
   network requirements.

3.4.1. Environmental Monitoring

   In this use case, LCs measure environmental data (e.g. temperatures,
   humidity, illuminance, CO_2, etc.) from several sensor devices at each
   measurement interval. LCs keep latest value of each sensor. BMS
   sends data requests to LCs to collect the latest values, then stores
   the collected values into a database. Operators check the latest
   environmental data that are displayed by the HMI. BMS also checks
   the collected data automatically to notify the operators if a room
   condition was going to bad (e.g., too hot or cold). The following
   table lists the field network requirements in which the number of
   devices in a typical building will be ~100s per LC.

```
+----------------------+------------+
| Metric               | Requirement |
+----------------------+------------+
| Measurement interval | 100 msec   |
|                      |            |
| Availability         | 99.999 %   |
+----------------------+------------+
```

Table 1: Field Network Requirements for Environmental Monitoring

There is a case that BMS sends data requests at each 1 second in
order to draw a historical chart of 1 second granularity. Therefore
100 msec measurement interval is sufficient for this use case,
because typically 10 times granularity (compared with the interval of
data requests) is considered enough accuracy in this use case. A LC
needs to measure values of all sensors connected with itself at each
measurement interval. Each communication delay in this scenario is
not so critical. The important requirement is completing
measurements of all sensor values in the specified measurement
interval. The availability in this use case is very high (Three 9s).

3.4.2. Fire Detection

In the case of fire detection, HMI needs to show a popup window with
an alert message within a few seconds after an abnormal state is
detected. BMS needs to do some operations if it detects fire. For
example, stopping a HVAC, closing fire shutters, and turning on fire
sprinklers. The following table describes requirements in which the
number of devices in a typical building will be ~10s per LC.

```
+----------------------+--------------+
| Metric               | Requirement  |
+----------------------+--------------+
| Measurement interval | 10s of msec  |
|                      |              |
| Communication delay  | < 10s of msec |
|                      |              |
| Availability         | 99.9999 %    |
+----------------------+--------------+
```

Table 2: Field Network Requirements for Fire Detection

In order to perform the above operation within a few seconds (1 or 2
seconds) after detecting fire, LCs should measure sensor values at a
regular interval of less than 10s of msec. If a LC detects an
abnormal sensor value, it sends an alarm information to BMS and HMI
immediately. BMS then controls HVAC or fire shutters or fire
sprinklers. HMI then displays a pop up window and generates the

alert message. Since the management network does not operate in real
time, and software run on BMS or HMI requires 100s of ms, the
communication delay should be less than ~10s of msec. The
availability in this use case is very high (Four 9s).

3.4.3. Feedback Control

Feedback control is used to keep a device state at a certain value.
For example, keeping a room temperature at 27 degree Celsius, keeping
a water flow rate at 100 L/m and so on. The target device state is
normally pre-defined in LCs or provided from BMS or from HMI.

In feedback control procedure, a LC repeats the following actions at
a regular interval (feedback interval).

1. The LC measures device states of the target device.

2. The LC calculates a control value by considering the measured
    device state.

3. The LC sends the control value to the target device.

The feedback interval highly depends on the characteristics of the
device and a target quality of control value. While several tens of
milliseconds feedback interval is sufficient to control a valve that
regulates a water flow, controlling DC motors requires several
milliseconds interval. The following table describes the field
network requirements in which the number of devices in a typical
building will be ~10s per LC.

Metric	Requirement
Feedback interval	~10ms - 100ms
Communication delay	< 10s of msec
Communication jitter	< 1 msec
Availability	99.9999 %

Table 3: Field Network Requirements for Feedback Control

Small communication delay and jitter are required in this use case in
order to provide high quality of feedback control. This is currently
offered in production environment with hgh availability (Four 9s).

4. Security Considerations

   Both network and physical security of BAS are important. While
   physical security is present in today's deployment, adequate network
   security and access control are either not implemented or configured
   properly. This was sufficient in networks while they are isolated
   and not connected to the IT or other infrastructure networks but when
   IT and OT (Operational Technology) are connected in the same
   infrastructure network, network security is essential. The
   management network being an IP-based network does have the protocols
   and knobs to enable the network security but in many cases BAS for
   example, does not use device authentication or encryption for data in
   transit. On the contrary, many of today's field networks do not
   provide any security at all. Following are the high level security
   requirements that the network should provide:

   o Authentication between management and field devices (both local
      and remote)

   o Integrity and data origin authentication of communication data
      between field and management devices

   o Confidentiality of data when communicated to a remote device

   o Availability of network data for normal and disaster scenario

5. IANA Considerations

   This memo includes no request to IANA.

6. References

6.1. Normative References

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