GW proposals for revised 4.1 with new figure 1 and text at the end of 4.1 as requested by comment resolution plus GW resolution of additional comments as noted.

**4.1 Control Loop Basic Model**

**4.1.1 Control loop operation**

Industrial network applications are based on three main types of building blocks which may be combined in one device or provided as separate devices interconnected through a suitable communication network.

These basic building blocks are;

* Sensor applications which provide input measurements indicating the state of a parameter being monitored or controlled,
* Controller applications which operate on combinations of measurements and external demand settings to develop output requests,
* Actuator applications which implement output requests as physical changes to the process or machine under control, such as a level in a storage tank, the speed of a printing press, or movement of a robot.

A control loop is formed when the process or machine responds to the actuator output and produces a new measured value at the sensor. The complete loop is shown in Figure 1 where the application devices are connected as end stations of a TSN infrastructure.



Figure 1 – Data flow in a control loop

In operation, the sensor application samples the measured value and the sampled values are transferred through the network as data packets for the controller to compare with the demand value. After any computational time, the required output is transferred from the controller to the actuator for implementation as a change in the external process.

This sequence repeats continuously as a regular operation using a local or a network time base. For good control, the sequence repetition rate needs to be 5 to 10 times faster than the time constant of the process response.

Control Latency or time delay between the sensor input and actuator output is a critical factor in all types of control and needs to be minimized and bounded.

Components of the Control Latency time, are shown as levels in Figure 1;

* Application time for sampling, computation and processing within each device. These are device specific and known to the device makers.
* Network Access time for data transfer through the Upper Layer DLL, MAC and PHY layers within each device These are set by the TSN components used by the device makers.
* Network & Bridge scheduling and transfer time through the external TSN network and bridges. These are set by the TSN configuration process which allocates available bandwidth and priorities to various types of application messages.

To support design of TSN based applications, tools are needed to predict the total end-to-end latency time for a planned installation.

During system operation TSN, management services are needed to measure and report actual latency time from “MAC interface-to-MAC interface”.

This is essential for diagnostics and checking the performance of an installed network.

**<Note to Editor: End of GW Contribution to 4.1.1 >**