HART COMMUNICATION FOUNDATION

# Control with WirelessHART

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Attention: Foundation Director
HART Communication Foundation
9390 Research Boulevard
Suite I-350
Austin, TX 78759, USA
Voice: (512) 794-0369
FAX: (512) 794-3904
http://www.hartcomm.org

**Synopsys:**

The WirelessHART standard is the first open wireless communication standard for measurement and control in the process industries. It uses wireless mesh networking between field devices, as well as other innovations, to provide secure, reliable digital communications that can meet the stringent requirements of industrial applications.

This is one of a series of papers helping users recognize the benefits of WirelessHART, as well as addressing specific questions about WirelessHART.

For nearly two decades, HART Communication has been the process industry standard for secure, simple, and reliable operations. New capabilities and wireless communication introduced with HART version 7, compliment established practice and expand the use of HART Communication into new areas and applications.

WirelessHART was designed specifically to support the wide range of process-industry use cases from simple monitoring to closed loop control. Testing and field trials with wireless devices have demonstrated that the communication accuracy, stability, total performance, and reliability can meet the demands of industrial process monitoring and control applications.

Control application requirements for sampling intervals, jitter, and latency were specifically addressed and designed into the WirelessHART technology. In fact, control performance with WirelessHART can be comparable to that of a wired system using traditional field buses. Let's look at some of the factors that can come up in considering WirelessHART for control applications.

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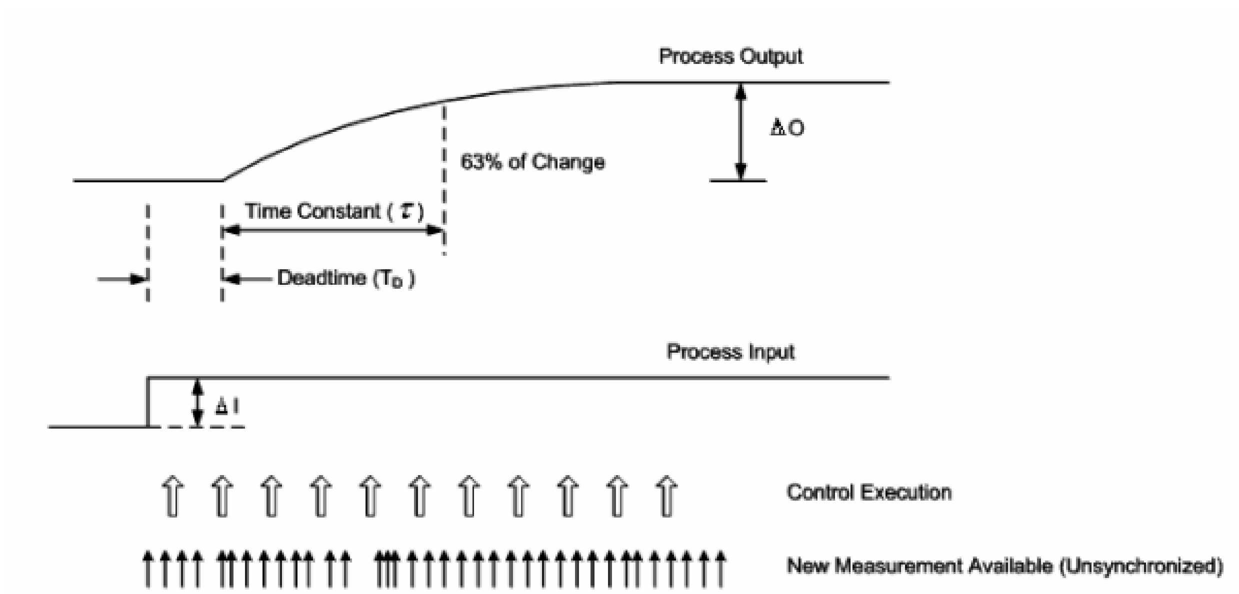
**Sampling intervals**

WirelessHART allows sampling intervals that meet the requirements of most control loops while at the same time minimizing the impact on field-devices that may be powered by a battery.

The typical rule of thumb is that feedback control should be executed 4-10 times faster than the process response time, where response time equals the process time constant plus deadtime.

Because measurement systems are often unsynchronized with the control system, measurement values are typically sampled as much as 2-10 times faster than the process can respond (Figure 1 below).

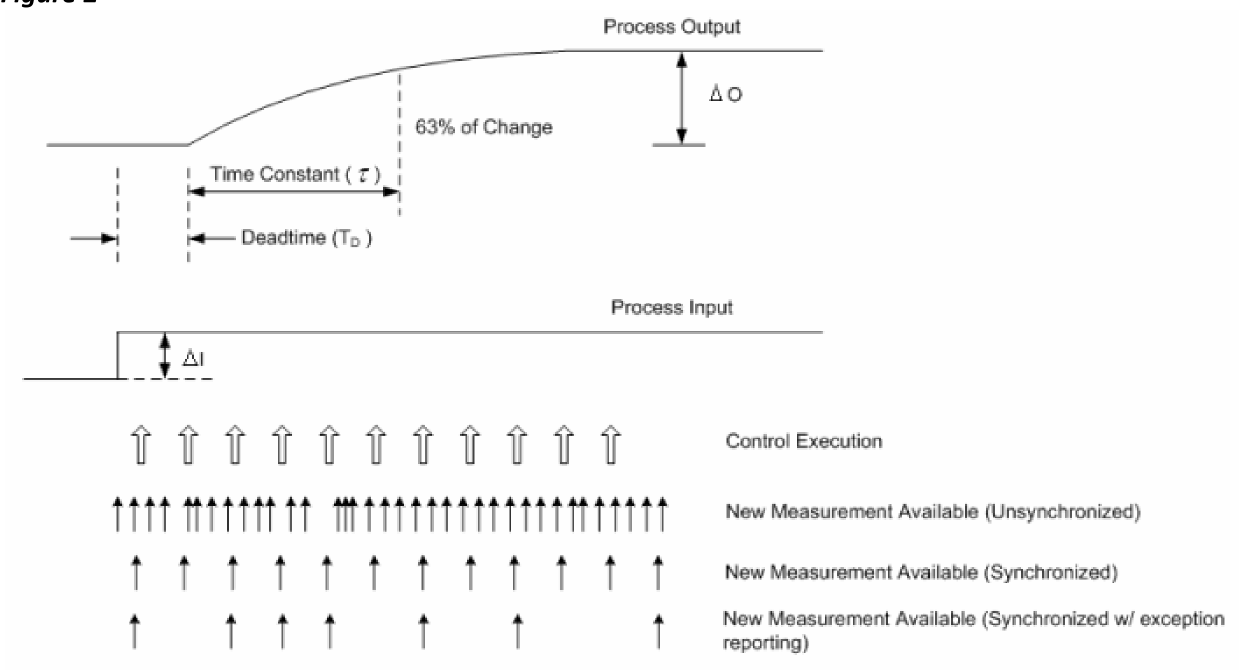


With wireless systems, however, it's desirable to reduce the frequency that measurements are taken and communicated in order to extend measurement-device battery life.

The ability to schedule communications with WirelessHART makes this easy to do without compromising control reliability. Figure 2 adds these two methods to the previous diagram:

- Synchronized. Measurements are taken and transmitted only (and exactly) when they're needed for control execution.
- Synchronized with exception reporting. Measurements are taken at scheduled intervals – for example, 4-10 times faster than the process response time – but transmitted only if the measurement has changed by a specified amount or if the time since the last communication exceeds a specified interval.

***Figure 2***



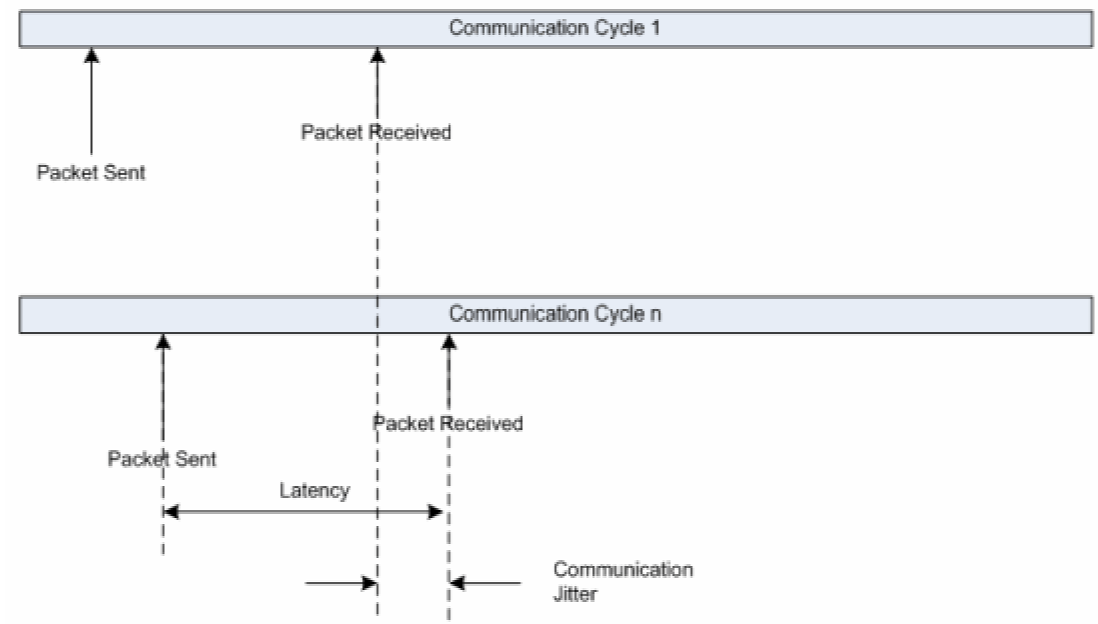

More-frequent communication of measured values is certainly possible and in the case of line powered devices can work similar to wired networks. In the case of battery powered or devices where energy conservation is important, WirelessHART offers users the opportunity to find an application's optimum balance between communication intervals and battery life.

**Latency and Jitter**
Effective control requires timely access to measurement and control information. A system's ability to meet its control performance requirements can be affected both by delays (latency) and variation (jitter) in when the information is available.

In some systems, latency and jitter can start with the timing of the measurements themselves. But WirelessHART is a time-synchronized protocol, with every device having a common sense of time accurate to 1 millisecond across the entire network – a capability not available in many other protocols. The measurement software and circuitry use this sense of time in scheduling measurements, all but eliminating delays and variation in measurement timing.

Latency and jitter can also be introduced when data is communicated – for example, from a transmitter to a gateway. In this case, latency is the time it takes for a communication packet to make its way from the source to the destination, while jitter is variation in latency between different communication cycles (Figure 3). Excessive latency (which effectively adds deadtime to the process) and jitter (which adds error into the control calculations) can lead to significant degradation in control performance.

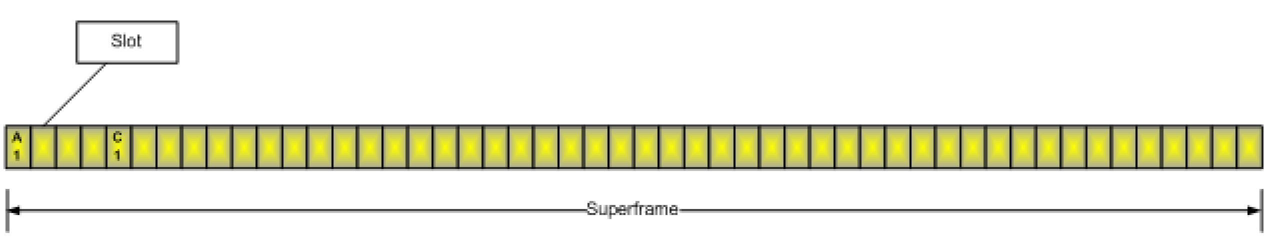
***Figure 3***




In direct communications, WirelessHART has a transmission rate that is faster than some traditional wired field bus technology. For example, if the communication rate is 31.25 kilobits/second, the communications delay will be 32 microseconds/bit. WirelessHART has a much faster communications rate – 250 kilobits/second -- so the delay introduced by the communications rate is only 4 microseconds/bit.

Since a typical WirelessHART message is 128 bytes, the time for complete message transmission is 4 milliseconds. Each transmission and its corresponding acknowledgement occur within a 10-millisecond "time slot" in a periodic communication Superframe or macrocycle (Figure 4).

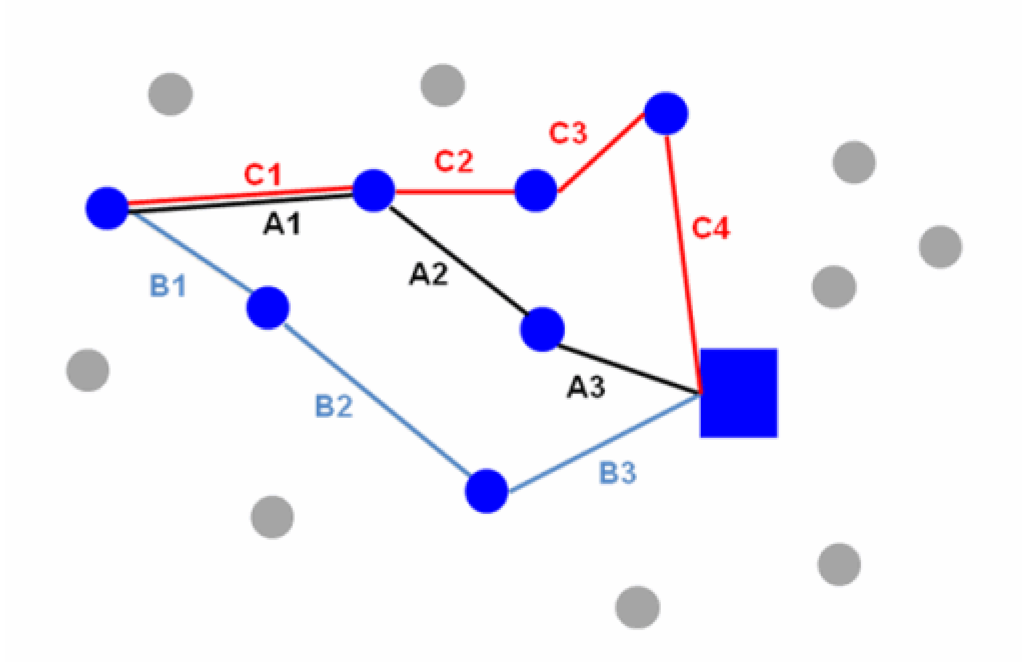
***Figure 4.***



However, in many scenarios communications require more than one time slot for a message to travel from the source to the destination. Let's look at one such scenario.

If a communication can't reach its destination directly, it can "hop" from node to node to bridge the gap or circumvent obstructions. This ability to route around physical obstacles or interference is a core feature of the WirelessHART mesh technology. Figure 5 shows three paths a communication might follow from the device on the left to the gateway on the right.

***Figure 5***




Changing the route the data travels can contribute to variation in communication time (jitter). Although each additional hop increases latency, in typical applications the average delay is well within the requirements for control. We can illustrate this with an example.

In most cases, a WirelessHART network will be able to retry a failed message in the next time slot or the one following. For our example we'll assume it takes 10 milliseconds to process a message and assign it to another time slot. Path A in Figure 5 could therefore produce as much as 50 milliseconds of total latency (10ms + [10ms + 10ms] + [10ms +10ms]). Path B has the same number of hops and thus the same communications latency. But Path C has an additional hop, bringing total communications latency to 70 milliseconds. This timing difference introduces a 20-millisecond jitter in the communications. (In many cases the routing device will be able to retry in the next slot, which would reduce the total latencies to 30 milliseconds for Paths A and B and to 40 milliseconds for Path C.)

Experience in hundreds of wireless field device installations shows that communications latency on average is much lower than in this example. In real plant settings, typically 30% of the devices communicate directly with the gateway or network access point (10 milliseconds) and about 50% are one hop away (30 milliseconds). The remaining 20% may be 3-4 hops. Using these numbers from actual plant installations, the average latency time will be about 30 milliseconds.

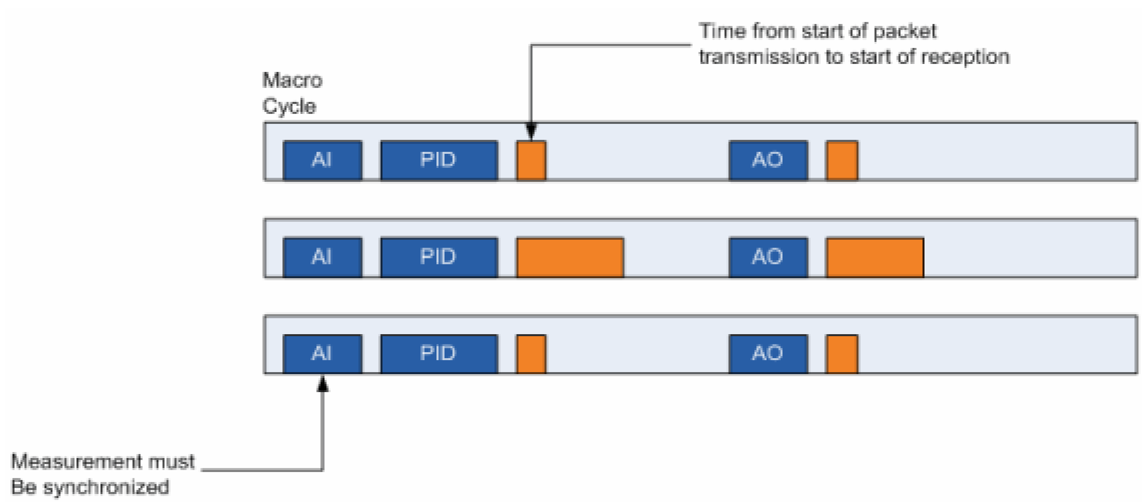
Existing installations also show that network reliability is typically greater than 99%, so the latency time will not vary significantly between communications – effectively eliminating the effect of jitter.

**But is it fast enough for control?**
Communications latency does not affect control as long as the delay is small compared to the process response time. Appropriate scheduling of transmissions across the time slots in a macrocycle can ensure the data reaches its destination when needed.

For good control we need to be able to read the control measurement, communicate the measurement to a controller, execute the control function, and communicate the output back to the target in one-half the process time constant. Most control loops are 1 second or more, so for a 1-second control loop we would need to be able to perform all of these steps within 500 milliseconds.

Let's see how this works with the example control loop shown in Figure 6. In this example, the measurement is processed in the field device, the control algorithm runs in the gateway, and the actuation occurs in a valve that's the same "hop depth" from the gateway as the measurement device. The total span of the cycle includes the AI, PID, AO, and communication times.

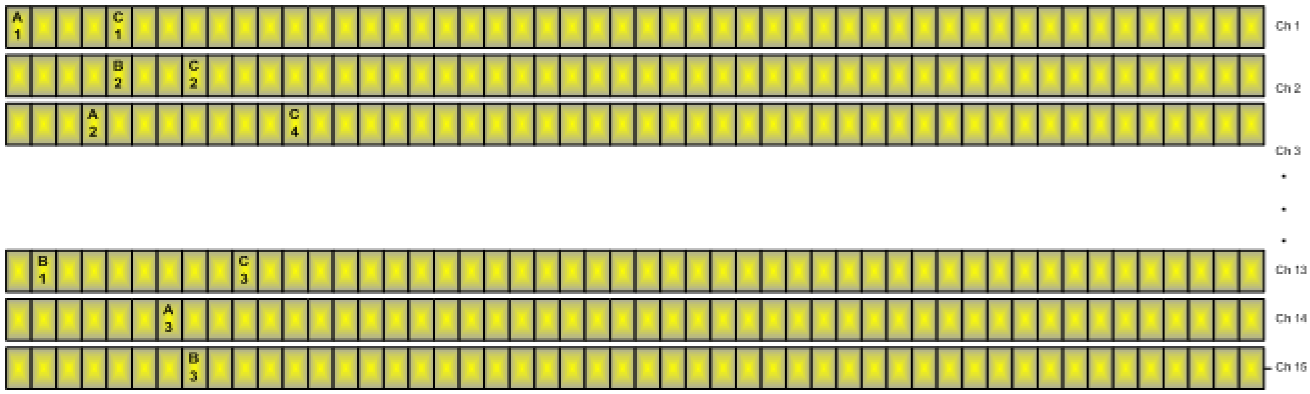
***Figure 6***




Using the numbers from our earlier example, each communication – from the measurement device to the gateway, and from the gateway to the valve -- would take 70 milliseconds. If we further assume that the control execution time inside the gateway is very small, then we can assume that the control loop will execute in 140-150 milliseconds – well below the required 500 milliseconds.

A typical network schedule to support this scenario is shown below. The individual communications shown earlier in Figure 5 are distributed both across the 50 time slots in each macrocycle and across the 15 radio-frequency channels used by WirelessHART.

***Figure 7***




As this example shows, 500-millisecond macrocycles are easily achievable even when multiple hops are assumed in the communication. This is fast enough for typical control loops, which in most cases are much slower than our example.

(The diagram also shows that there is almost no impact to the bandwidth of the system. In fact, less than 12% of available slots are needed to do 10 high speed control loops in parallel.)

In this example we illustrated what would happen if the communications took 70 milliseconds. As mentioned earlier, however, actual plant experience shows that average latency times are about 30 milliseconds. Using 30 milliseconds in our calculations reduces the loop execution time to less than 100 milliseconds and reduces the number of communications in the network. If it is important to reduce the delays introduced by multiple hops, additional network access points can be used.

It is also possible to further reduce communication latency and address higher speed control applications by using peer-to-peer communications between field devices. Running the control algorithm in a field device eliminates the need for wireless hops between that device and a gateway-resident algorithm. Such an arrangement may also use less bandwidth, allowing for multiple control loops with minimal impact to overall bandwidth. Of course, using this strategy is dependent on whether there are additional interactions between the control loops.

This example used wireless network layouts that were more complex than what experience has found in actual plant environments. We could have also incorporated multiple access points to shorten communication paths, and allocated additional communication resources to further enhance the effectiveness of the WirelessHART network. And because all WirelessHART measurements include a timestamp, we could have used the timestamp in the control algorithm to further reduce the impact of any latency and jitter.

**Conclusion**

Even without utilizing any of these additional features, the example shows that the overall control performance of a typical WirelessHART network is comparable to that of traditional wired field buses. The WirelessHART protocol allows for secure, highly reliable, low latency control with almost no impact on the bandwidth and absolutely no impact on process performance.

WirelessHART is simple, reliable, and secure.