PROFINET – RT vs IRT
Communication Basics
Ethernet + Profinet = Industrial Ethernet

• Profinet is complimentary to Ethernet
• Profinet is “Industrial Ethernet”
• Profinet devices include IO-controllers and IO-Devices
• Profinet is “Fast Ethernet” ie 100Mbit/s Full Duplex
• Profinet devices, connectors and cable are suited to industrial applications
Communication Basics
Transmission methods

- PROFINET follows a “Consumer-Provider” Model
- **Cyclic**, deterministic data transfer for time-critical applications
- Prioritization of time-critical data
- **Acyclic** data transmission for configuration, monitoring and diagnostics/alarming

![Diagram showing PROFINET communication between IO-Supervisor, IO-Controller, and IO-Device]

- **Cyclic Data:** Process Data
- **Acyclic Data:** Parameterization, Diagnostics, Monitoring/Controlling
- **Acyclic Data:** Configuration, Alarms
Communication Basics
Profinet communication channels

None Real Time (NRT) <100ms cycle
- **Acyclic**
- Uses TCP/IP
- Left lane

Real Time (RT) <10ms cycle
- **Cyclic**
- Skips the TCP/IP layers
- Over taking lane

Isochronous Real Time (IRT) <1ms cycle
- **Cyclic**
- Reserved Bus lane
Communication Basics
Controller selection

RT
• ~80% applications require RT only
• In this case any controller is suitable

IRT
• The remaining applications will require high speed capabilities
  • Synchronised Motion
  • Precision Measuring
  • Precision IO
• Ethernet switches can be used but selection guidelines must be followed
  • ie IRT = Conformance Class C

<table>
<thead>
<tr>
<th>Function</th>
<th>Controller</th>
<th>IO-Controller</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S7-1500</td>
<td><img src="%E2%9C%93" alt="Checkmark" /></td>
</tr>
<tr>
<td></td>
<td>S7-1200</td>
<td><img src="%E2%9C%93" alt="Checkmark" /></td>
</tr>
<tr>
<td></td>
<td>S7-300 / S7-400</td>
<td><img src="%E2%9C%93" alt="Checkmark" /></td>
</tr>
<tr>
<td></td>
<td>Open Controller</td>
<td><img src="%E2%9C%93" alt="Checkmark" /></td>
</tr>
</tbody>
</table>
Communication Basics
OSI 7 layer model

- Each layer adds processing time
- NRT is used for configuration, web server, diagnostics and other none real time tasks
- RT is typically used for standard cyclic data acquisition
- IRT is used for high speed data transfer
Communication Basics
OSI 7 layer model – closer look

<table>
<thead>
<tr>
<th>Layer</th>
<th>Services</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Application</td>
<td>HTTP, SNMP usw.</td>
</tr>
<tr>
<td>6</td>
<td>Presentation</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Session</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Transport</td>
<td>TCP, UDP</td>
</tr>
<tr>
<td>3</td>
<td>Network</td>
<td>IP</td>
</tr>
<tr>
<td>2</td>
<td>Data link</td>
<td>Ethernet</td>
</tr>
<tr>
<td>1</td>
<td>Physical</td>
<td>100 Base TX/FX</td>
</tr>
</tbody>
</table>

The OSI layer model for structured communication:

- **Physical Layer (1)**: 100 Base TX/FX
- **Data Link Layer (2)**: Ethernet
- **Network Layer (3)**: IP
- **Transport Layer (4)**: TCP, UDP
- **Session Layer (5)**: 
- **Presentation Layer (6)**: 
- **Application Layer (7)**: HTTP, SNMP usw.

### Services
- **Web pages, email, live pictures, etc.**
- **IO data**
Profinet RT
No synchronization of cycles

RT – Real Time:
• **Real-time communication** between controller and device
• Each device has its own update time
• Processing in the standard user program (e.g. OB1)

Reaction time (input-output)
• Best case: sum of all individual cycles
• Worst case: 2 x (sum of all individual cycles)

Time precision of output signal (OB1-output)
2 x sum of all cycles from CPU to output (T4 - T7)

Various uncoordinated cycles
• T1: sampling of input
• T2: backplane bus ET 200
• T3: Profinet I/O
• T4: CPU cycle (OB1)
• T5: Profinet I/O
• T6: backplane bus ET 200
• T7: setting output
Profinet IRT
Isochronous mode for fast reaction time

**System clock**

**T\textsubscript{i}:** Read in ALL inputs of ALL devices at a fixed predefined time

**OB:** processing in the CPU

**T\textsubscript{0}:** Writes ALL outputs of all devices at a fixed predefined time

**IRT – Isochronous Real Time:**
- All **cycles** are **synchronized** with each other
- **Special hardware** is needed ie HF modules
- IRT packets are transmitted in a **reserved bandwidth**
- **Isochronous mode: Synchronized processing** in the user program using "synchronous cycle" OB6x (T8)
Profinet IRT
Additional capabilities

**Cycle time**

Typical 500 µs cycle
CPU1518 V2.0: **125 µs**

By optimized packing of data the transmission time gets reduced:

- Less time on LAN
- More time of the cycle for Sync-OB
- More time for Non-IRT on LAN

**Oversampling**

Peripheral module separates PN cycle into smaller sampling cycle. All samples are sent to the PLC.

**Time based IO**

Rising and falling edge of signal are transmitted with timestamp → high precision signal capturing

Outputs triggered with timestamp → high precision reaction

![Diagram](image)

Value capturing

Sending 16 values

System update time

Synchronous OB

\[ t_\Delta := t_2 - t_1; \]
\[ s_\Delta := v \cdot t_\Delta; \]
## Profinet RT/IRT
### Functional Overview

<table>
<thead>
<tr>
<th>RT</th>
<th>IRT</th>
<th>Isochronous</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Real-time communication</td>
<td>• Real-time communication with reserved bandwidth and synchronized cycles</td>
<td>• Real-time communication with synchronized OB61</td>
</tr>
<tr>
<td>• Update time &gt;=250µs</td>
<td>• Update time &gt;=125µs</td>
<td>• Synchronization of the user program to all other synchronized cycles</td>
</tr>
<tr>
<td>• Applications:</td>
<td>• Special hardware</td>
<td>• Requirement for further functions e.g. Oversampling and time-based IO</td>
</tr>
<tr>
<td>• manufacturing engineering</td>
<td>• Requirement for isochronous mode</td>
<td>• Applications:</td>
</tr>
<tr>
<td>• building automation</td>
<td>• Applications:</td>
<td>• Motion control</td>
</tr>
<tr>
<td>• automation equipment</td>
<td>• Precise reactions</td>
<td>• Precise reactions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• measuring technology</td>
</tr>
</tbody>
</table>
Profinet IRT
Key requirements

• Define Topology in TIA ‘Topology view’
  o Ensures optimised data transfer
  o Allows scheduled transfers

• Configure interface real time settings and set synchronization role

• Ensure correct settings for the sync domain
  o Optional High performance
  o Optional Fast forwarding
Profinet IRT
Key requirements

Insert Synchronous OB6x or Motion OB

Enable Isochronous mode on each IO Device
• Will ensure IO is sync’d with Motion or OB6x
IRT on the oscilloscope vs. TIA Portal

- TIA / Step7 calculates timing beforehand
- Reaction time predefined
- Live result as expected
Profinet IRT
Time slice model

Partitioning of the bus cycle
- Separate time slices (time domains) for IRT and rest (RT, TCP/UDP,..)
- High precision cycle synchronization
- Based on optimized switch ASIC → special hardware needed

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Diagram:
- IRT-channel
- Standard channel
- IRT-channel
- Standard channel
- IRT-channel

Cycle 1 → Cycle 2 → Cycle n

= time domain

E.g. 1 ms position control cycle

- Isochronous communication
  - IRT-data
- RT/Standard communication
  - RT-data / TCP/IP-data

Syncronization
Profinet IRT
Time slice model in detail

Fixed bandwidth for IRT in theory:

<table>
<thead>
<tr>
<th>Cycle 1</th>
<th>Cycle 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRT-channel</td>
<td>Standard channel</td>
</tr>
<tr>
<td>IRT-channel</td>
<td>Standard channel</td>
</tr>
</tbody>
</table>

Send clock 250µs
PN 0% - 100µs
0% - 250µs

Send clock 500µs – 1ms
PN 0% - 100µs
0% - 250µs

Send clock > 1ms
PN 0% - 100µs
0% - 500µs

Overview in TIA Portal:

1. Reserved bandwidth can be set in TIA Portal
2. Used bandwidth is displayed separately for IRT and RT
Profinet IRT
Fast forwarding

- To forward frames, a device needs to see the frame ID

- This typically takes 1440ns

- Using performance mode, this is improved to 320ns

- Frame ID leads the Profinet frame
Profinet IRT
Dynamic Frame Packing

• Each DFP frame includes a specific device data along with other devices on the line

• Each device takes its data and forwards on

• This leads to an overall improvement in network bandwidth
Profinet IRT
Fragmentation

• A complete standard Ethernet TCP/IP frame takes 125uS so cycle time cannot be reduced

• Performance mode allows fragmentation of these frames into sub frames

• Cycles times <250us are achievable

• Fragmented frames reassembled at the target device

• Fragmentation requires one port to be blocked on the IO controller
IRT Use Case 1: Motion Control

Flying Saw

- Saw axis is synchronised to the primary feed axis
- Configuration of Topology
- Each Servo drive is assigned to a Technology Object (TO)
  - Primary = Positioning axis
  - Saw = Synchronous axis
- Synchronisation done via OB91 MC-Servo
Measure box length on conveyor

- Speed detection can be from various sources
  - Sinamic Drive/Servo
  - Profinet encoder
  - TM Timer DIDQ and a suitable encoder

- Sensor input via TM Timer DIDQ 16x24V or TM Timer DIDQ 10x24V

- Sensor input rising and failing edges are time stamped

- Measuring function block is called within Synchronous OB6x

- Independant of varying cyclic variations of standard OBs
IRT Use Case 3: Precise Control

Precise hydraulic pressure control

- Utilises ET200SP TM Pulse 2x24V

- Various output modes to suit proportional valve
  - PWM
  - Pulse train
  - On/Off delay
  - Freq output
  - PWM with DC motor

- Dithering can be superimposed on the PWM output to ensure easy movement even with sticky valves

- Isochronous mode improves control properties but not essential
IRT Use Case 4: Precise measurements

CAM shaft measurement

- Measure each cam during rotation with high accuracy
- Measurements are synchronously captured while in motion
- Program code is managed within Synchronous OB6x
- Due to high speed measurements, machine cycle is reduced
IRT Use Case 5: Measured values

Signal Oversampling

• Allows high speed inline testing of product

• Can be activated in ET200SP High Speed (HS) modules

• Requires distributed IO

• Oversample range 2 - 16 sub cycles/cycle

• Requires Isocronous mode via OB6x
1. RT monitoring via Oscilloscope

2. TIA Portal Settings

3. Isochronous OB + Settings

4. IRT monitoring via Oscilloscope