

The Bowler RPC

A zeroconf protocol for creating PC-microcontroller networks

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1 Overview

1.1 Motivation

1. We want a PC to talk to any device which is running some Bowler software. We want this software to require minimal to no configuration from the user.
2. We want to support any resource attached to the device with minimal to no configuration from the user.
3. We require the communications between the PC and device satisfy hard real-time requirements: 5ms Round Trip Time (RTT), 100ms timeout.
4. Therefore, we settle on a zeroconf protocol which can be used by the PC to establish a Remote Procedure Call (RPC) with the device.

1.2 Configuration Process

The PC-device RPC is established in the following order

1. The PC connects to the device using some Physical Layer implementation.
2. The PC sends discovery packets to the device to tell the device which resources are connected to it. The device may reject any packet if it deems the resource invalid.
3. Once all resources have been discovered, the discovery process is finished and the PC and device may use the configured RPC.

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2 Discovery

2.1 Packet Format

2.1.1 General Discovery Packet Format

Figure 1 shows what the PC sends the device to initiate a discovery operation. Any additional operation-specific data is sent in the Payload section. The entire packet is 64 bytes.

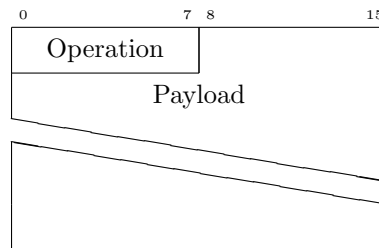


Figure 1: Discovery-time send packet format.

- Operation: 1 byte
 - The Operation field states the operation the packet performs.

Figure 2 shows what the device sends the PC to complete a discovery operation. Any additional operation-specific data is sent in the Payload section. The entire packet is 64 bytes.

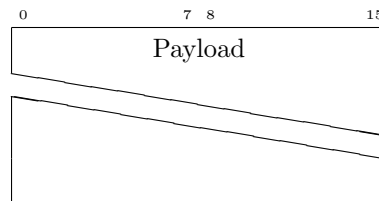


Figure 2: Discovery-time receive packet format.

2.1.2 Discovery Packet

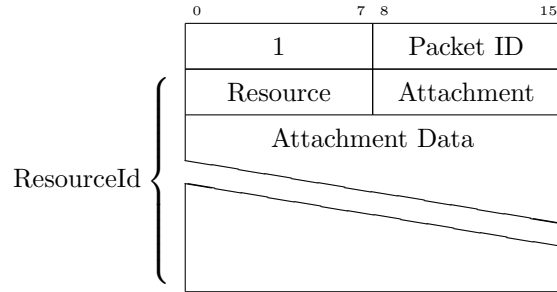


Figure 3: Discovery send packet.

- Packet ID: 1 byte
 - The Packet ID field is a new ID for the packet being discovered.
- Resource: 1 byte
 - The Resource field is the type of the resource. It is the `ResourceId.resourceType.type`.
- Attachment: 1 byte
 - The Attachment field is the type of the attachment point. It is the `ResourceId.attachmentPoint.type`.
- Attachment Data: 1+ bytes
 - The Attachment Data field is any data needed to fully describe the Attachment. It is the `ResourceId.attachmentPoint.data`.

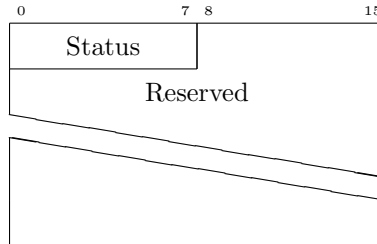


Figure 4: Discovery receive packet.

- Status: 1 byte
 - The Status field encodes the status of the discovery operation. 1 = Accepted, 2 = Rejected.

2.1.3 Group Discovery Packet

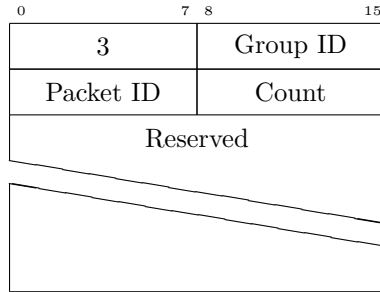


Figure 5: Group discovery send packet.

- Group ID: 1 byte
 - The Group ID field is the ID for the group being made. Future group member discovery packets will need this ID to add resources to the correct group.
- Packet ID: 1 byte
 - The Packet ID field is the ID for the packet the group will use. All resources in the group get packed into one packet.
- Count: 1 byte
 - The Count field is the number of resources that will be added to the group.

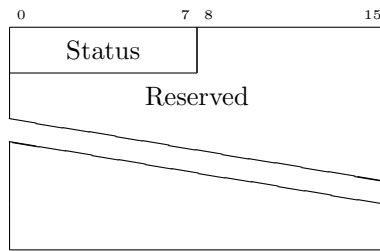


Figure 6: Group discovery receive packet.

- Status: 1 byte
 - The Status field encodes the status of the discovery operation. 1 = Accepted, 2 = Rejected.

2.1.4 Group Member Discovery Packet

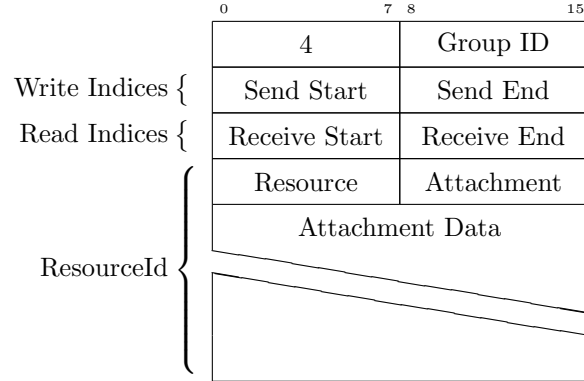


Figure 7: Group member discovery send packet.

- Group ID: 1 byte
 - The Group ID field is the ID for the group that this resource will be added to.
- Send Start: 1 byte
 - The Send Start field is the starting byte index in the send Payload for this resource's write data.
- Send End: 1 byte
 - The Send End field is the ending byte index in the send Payload for this resource's write data.
- Receive Start: 1 byte
 - The Receive Start field is the starting byte index in the receive Payload for this resource's read data.
- Receive End: 1 byte
 - The Receive End field is the ending byte index in the receive Payload for this resource's read data.
- Resource: 1 byte
 - The Resource field is the type of the resource. It is the `ResourceId.resourceType.type`.
- Attachment: 1 byte
 - The Attachment field is the type of the attachment point. It is the `ResourceId.attachmentPoint.type`.
- Attachment Data: 1+ bytes

- The Attachment Data field is any data needed to fully describe the Attachment. It is the `ResourceId.attachmentPoint.data`.

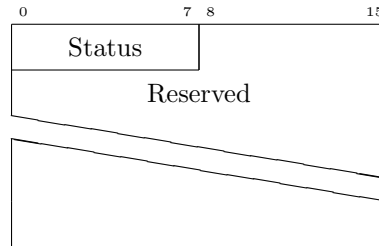


Figure 8: Group member discovery receive packet.

- Status: 1 byte
 - The Status field encodes the status of the discovery operation. 1 = Accepted, 2 = Rejected.

2.2 Discovery Process

2.2.1 Discovery

Sequence diagram for

1. Send discovery packet and get response (accepted).
2. Send discovery packet and get response (rejected).

2.2.2 Group Discovery

Sequence diagram for

1. Send group discovery packet and get response (accepted). Send multiple group member discovery packets and get responses (accepted).
2. Send group discovery packet and get response (accepted). Send multiple group member discovery packets and get responses (most accepted, some rejected).
3. Send group discovery packet and get response (rejected). Send multiple group member discovery packets and get responses (rejected).

3 RPC

3.1 Packet Format

3.1.1 Non-Group

Packets for non-group resources correspond to a single resource. These resources do not have any timing constraints.

The non-group send packet format consists of the write payload.

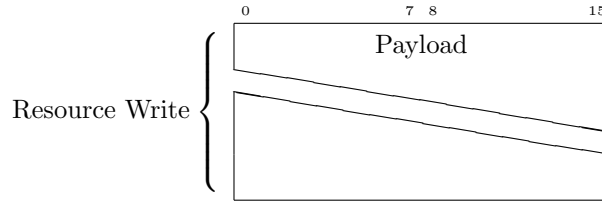


Figure 9: RPC send packet format.

The non-group receive packet format consists of the read payload.

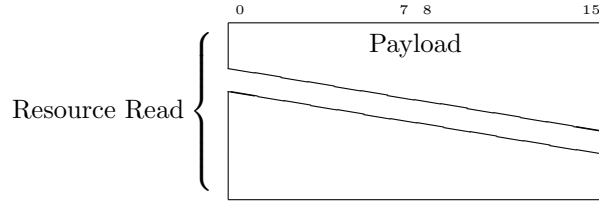
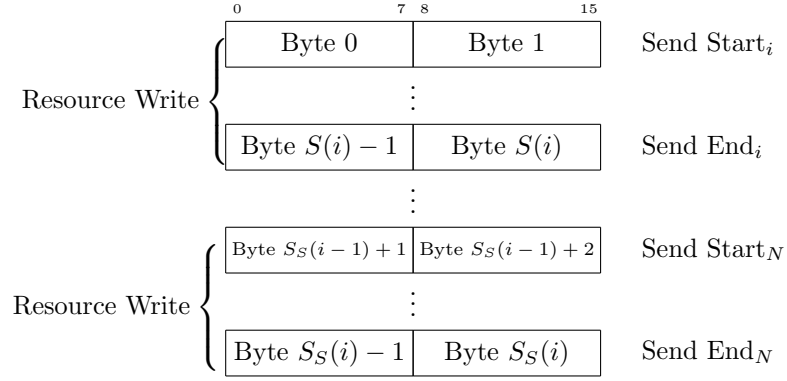


Figure 10: RPC receive packet format.

3.1.2 Group

Packets for group resources correspond to multiple resources whose write and read payloads are packed into a single packet. These resources typically have timing constraints and are therefore put into a group.

The group send packet format consists of packed resource write payloads as specified by the Send Start and Send End indices from the group member discovery packets.



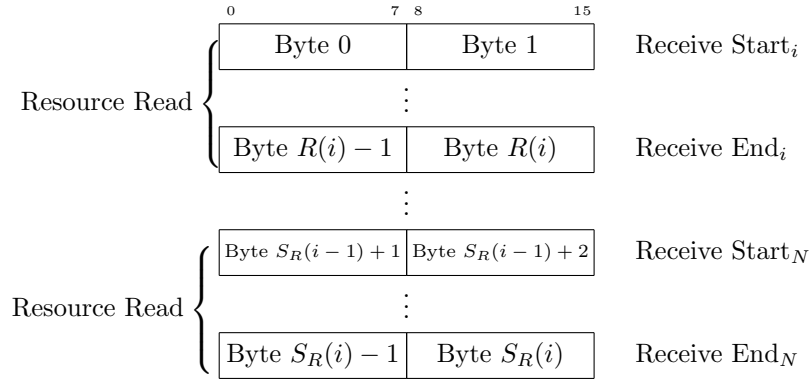
$$S_S(n) = \sum_{i=1}^n S(i) \quad (1)$$

$$S(i) = \text{Send End}_i - \text{Send Start}_i \quad (2)$$

$$i \in [1, N], N = \text{Count} \quad (3)$$

Figure 11: RPC send packet format.

The group write packet format consists of packed resource read payloads as specified by the Receive Start and Receive End indices from the group member discovery packets.



$$S_R(n) = \sum_{i=1}^n R(i) \quad (4)$$

$$R(i) = \text{Receive End}_i - \text{Receive Start}_i \quad (5)$$

$$i \in [1, N], N = \text{Count} \quad (6)$$

Figure 12: RPC receive packet format.

Glossary

device A microcontroller running an implementation of the Bowler RPC. 1, 3, 11

discovery A procedure in which the PC tells the Device which Resources are connected to it. 1, 3, 4, 5, 7

group A collection of Resources which must be written to/read from at the same exact time.. 5, 6, 8, 9, 11

group discovery A procedure in which the PC tells the Device about a Group. 7

group member discovery A procedure in which the PC tells the Device about a Resource which is part of a Group. 5, 8, 9

PC The host computer running the Bowler stack. 1, 3, 11

resource A hardware element connected to a Device; typically an actuator or sensor. 1, 4, 5, 6, 8, 9, 11

zeroconf Zero-configuration; the automatic creation a computer network. 1

Acronyms

RPC Remote Prodecure Call. 1

RTT Round Trip Time. 1