APPLICATION NOTE

AC500 MQTT
FAQS
Contents

1 Introduction ........................................................................................................................................ 4
  1.1 Scope of the document .............................................................................................................. 4
  1.2 Compatibility .............................................................................................................................. 4
  1.3 Application Examples .............................................................................................................. 4

2 FAQs ................................................................................................................................................. 5
  2.1 General Information's .............................................................................................................. 5
    2.1.1 What PLC types are supporting Mqtt? ........................................................................... 5
    2.1.2 How can I resolve my domain name into an IP address? ......................................... 5
    2.1.3 What is the required hardware infrastructure to send data to the Mqtt Broker? .......... 5
    2.1.4 What are the limitations of AC500-eCo PLC? ............................................................. 5
    2.1.5 Is Online Change supported? ......................................................................................... 5
    2.1.6 Do we have a Mqtt Broker on the PLC available? ....................................................... 5
    2.1.7 Do I need a battery for Mqtt? .......................................................................................... 5
    2.1.8 Do I need to set the date and time in the PLC? .............................................................. 6
  2.2 Mqtt Library ............................................................................................................................... 7
    2.2.1 Is QoS (Quality of Service) 0, 1 and 2 supported by the Mqtt library? ......................... 7
    2.2.2 When I try to connect, I got this error message
      MQTT_ERR_CONN_SERVER_CERT_NOT_VALID .......................................................... 7
    2.2.3 What to do if I receive error:
      MQTT_ERR_CONN_SERVER_CERT_NOT_PEM ......................................................... 7
    2.2.4 Is there a limitation in the length of cert file name at the input? .................................. 7
    2.2.5 From each location there are less than 10 signals. What is the fastest update rates for Mqtt? ...................................................................................................................... 7
  2.3 Certificates ............................................................................................................................... 8
    2.3.1 What formats for certificates are available? ................................................................. 8
    2.3.2 Where can I get the server cert for Azure? ...................................................................... 8
  2.4 Connectivity ............................................................................................................................ 9
    2.4.1 Do I need to configure a Gateway in my PLC to connect to the Internet? .................. 9
    2.4.2 What should be minimum specification for internet connection e.g. internet speed? ................................................................................................................................. 9
    2.4.3 Do I need any special coupler to connect to the Internet? ........................................... 9
    2.4.4 AC500 support only Ethernet based internet. If customer has only a Wi-Fi connection available, then is there any possibility to run Mqtt? ......................................................... 9
    2.4.5 Does Mqtt affect other protocols like ModbusTCP or reduce the communication speed? ............................................................................................................................. 9
    2.4.6 What is the limit of data which we can transferred by using Mqtt in one cycle? .......... 10
    2.4.7 How can we define the communication speed? ............................................................ 10
    2.4.8 Are any limitation of Tags in Mqtt? ................................................................................ 10
    2.4.9 In single message, how many parameters can we send? ........................................... 10
    2.4.10 Can we communicate with multiple IOT Hubs? ......................................................... 10
    2.4.11 In case of Internet disconnection, is there any option in PLC to locally buffer the data and restore buffered data with the timestamp once the internet connectivity resumes? .................................................. 10
    2.4.12 If data is stored with timestamp (data during the disconnection). How the system will do the priority for data
transfer for current data and old data (data from disconnection time). .......................................................... 11

2.5 Services in the Cloud........................................................................................................................................ 12

2.5.1 What normal settings / knowledge is needed for customer to store / view data on cloud? ........................................................................................................ 12

2.5.2 What is the hardware infrastructure like type/capacity of servers etc. required for building an on-premise cloud infrastructure? ........................................................................................................ 12

2.5.3 What are the licenses /subscriptions required of the Azure software’s? ................................................................................................................................. 12

2.5.4 What Edge services are required? .................................................................................................................. 12

2.5.5 Does Azure support QoS? ............................................................................................................................ 12

2.5.6 Does Azure support multiple connections with the same device? ........................................................................ 13

2.5.7 Does Azure support Retain flag? .................................................................................................................. 13

2.5.8 How to configure the services in the cloud? .................................................................................................. 13

2.6 Reference Solutions.......................................................................................................................................... 15

2.6.1 References of AC500 MQTT solutions? ........................................................................................................ 15
1 Introduction

1.1 Scope of the document

The most raised questions, regarding Mqtt are listed here. Please check also our Whitepaper for further information regarding Cyber Security. Some additional information can be found in the Automation Builder documentation.

1.2 Compatibility

The application example explained in this document have been used with the below engineering system versions. They should also work with other versions, nevertheless some small adaptations may be necessary, for future versions.

- AC500 V2 PLC
- AC500 V3 PLC
- Automation Builder

1.3 Application Examples

You can find two application examples here:

- Application Example AC500 MQTT & MS Azure - First steps and configuration
- Application Example AC500 MQTT & Mosquitto - First steps and configuration
2 FAQs

Here is a list of most asked questions.

2.1 General Information’s

2.1.1 What PLC types are supporting Mqtt?
The PM556 and above would be able to run a Mqtt application.
The PM5x4 PLCs do not have sufficient memory.
All V3 PLCs are supporting Mqtt.

2.1.2 How can I resolve my domain name into an IP address?
For both V2 and V3 PLCs, we have a DNS Resolve function block. For V3 PLC, this function block was available with AB V2.2.2.

2.1.3 What is the required hardware infrastructure to send data to the Mqtt Broker?
You need of course:
- PLC V2 or V3 hardware
- Router or any device that connects you to the internet

2.1.4 What are the limitations of AC500-eCo PLC?
Minimum PLC for usage of Mqtt is PM556-ETH and above.

2.1.5 Is Online Change supported?
Online Change is not supported if Mqtt is used together with a V2 PLC.

2.1.6 Do we have a Mqtt Broker on the PLC available?
Mqtt broker is not available for any AC500 PLC.
It is also not planned to support this.

2.1.7 Do I need a battery for Mqtt?
Mqtt itself do not requires a battery.
But you know, Mqtt is using TLS to encrypt the communication. Therefore, we need certificates. This certificate has a validation time. The PLC time is required to check if the certificate is valid.
After reboot of the PLC, the date and time in the PLC is set to 1970 if no battery is plugged. Then you are not able to establish a connection again.

2.1.8 Do I need to set the date and time in the PLC?

It’s recommended to always set the time and date in the PLC.

For Mqtt and the Certificates, it is required to have a valid date and time set in the PLC.
2.2 Mqtt Library

2.2.1 Is QoS (Quality of Service) 0, 1 and 2 supported by the Mqtt library?
The QoS 0, QoS1 and QoS2 are supported by the Mqtt library.
Please check also the other FAQs, there are some limitations for Azure, AWS and so on.
If a value is published with a QoS level and the Done output is set, then the telegram was sent correctly. If there is a timeout or any other Err triggered, then the function block must be called again, until the Done is true and no error appears.

2.2.2 When I try to connect, I got this error message
MQTT_ERR_CONN_SERVER_CERT_NOT_VALID
This will be solved if you set the date and time inside the PLC.
Please use a battery to restore the date and time in the PLC after a reboot.

2.2.3 What to do if I receive error: MQTT_ERR_CONN_SERVER_CERT_NOT_PEM
Invalid format of the server certificate. Please check the point 2.3.2

2.2.4 Is there a limitation in the length of cert file name at the input?
We have to differentiate between V2 and V3 PLC:
V2: The max length is 255 chars including path “sdcard/” and name of the cert file itself.
Please be sure, that V2 PLC has the 8.3 file format. This means max. 8 chars for the filename.
V3: The max length is 255 chars including path “sdcard/” and name of the cert file itself.
V3 PLC can have more than 8 chars for the filename.

2.2.5 From each location there are less than 10 signals. What is the fastest update rates for Mqtt?
This depends on your application and your PLC type.
We can send Mqtt telegrams with 5ms interval to the cloud.
Of course, I have used a PM5670.
For eco PLC I do not have any benchmark yet.
2.3 Certificates

2.3.1 What formats for certificates are available?
- PEM Format → asci (readable)
- DER format → binary (not readable)

2.3.2 Where can I get the server cert for Azure?
This is the certificate that Azure is using. We are using MS Root CA certificate “Baltimore Cyber Trust Root”. This can be extracted from Windows CertMgr (Run "certmgr.msc") for example

Please be sure, that you extract the file as “Base-64 encoded:”
2.4 Connectivity

2.4.1 Do I need to configure a Gateway in my PLC to connect to the Internet?

Yes, you need to set the gateway in the PLC to connect to the internet. Please use the IP-Configuration tool to set the IP address and gateway.

2.4.2 What should be minimum specification for internet connection e.g. internet speed?

We have tested here with our bandwidths. It is around 6 Mbit/s. But I expect that also slower bandwidths are possible. But this must be tested for each application.

2.4.3 Do I need any special coupler to connect to the Internet?

No additional couplers are required. You need only an internet connection. You can plug your internet connection to the PLC, set the gateway in the PLC and use the Mqtt library.

2.4.4 AC500 support only Ethernet based internet. If customer has only a Wi-Fi connection available, then is there any possibility to run Mqtt?

Yes, you can use a Router. The router receives the Wi-Fi signal and you can connect the network cable to the same Router to get internet access.

In addition, there are also Wi-Fi Repeater on the market available they provide the possibility to connect a network cable directly to it.

2.4.5 Does Mqtt affect other protocols like ModbusTCP or reduce the communication speed?

You can use different protocols like Modbus TCP, Mqtt, CoDeSys ETH, UDP and so on the same line(same network cable – ETH port). Be sure that if you have much traffic on the line, mostly the Scada creating a high load on the line, this can affect other protocols.

For example, the Panel took longer to update the tags. Or you receive some timeouts. You can think about, to separate the networks. At the end it’s depends on the application and the number of tags und update rates.
2.4.6 What is the limit of data which we can transferred by using Mqtt in one cycle?

The limitations of TCP are based. Mqtt is TCP based so, you have 1460-byte data for a single telegram. If there are more data transferred, the TCP stack will separate the telegrams.

2.4.7 How can we define the communication speed?

The communication speed is dependent of your cycle time in the PLC and how fast you trigger the MqttPublish() function block.

2.4.8 Are any limitation of Tags in Mqtt?

Mqtt has no limitations of how many tags you can send to the Broker.

2.4.9 In single message, how many parameters can we send?

There is not a limitation in number of parameters. There is limitation in number of bytes you want to send. In a single telegram, the TCP default is 1460 byte. If more bytes must be send, the IP Stack split the data in separate telegrams.

2.4.10 Can we communicate with multiple IOT Hubs?

With one instance of MqttConnect() you can connect to one IoT Hub. But, you can use more than one MqttConnect() instances to connect to different IoT Hubs.

2.4.11 In case of Internet disconnection, is there any option in PLC to locally buffer the data and restore buffered data with the timestamp once the internet connectivity resumes?

The data will not be stored automatically if no Internet connection is available. This must be programmed manually or using Data Logger for V2 PLCs.

For V3 this must be done in an own application.

The Mqtt library provides a MqttPing() function block. There you can check if you can ping your Broker. Or use ICMP Ping function block to check if you can ping a server in the internet.

BUT: If the internet connection is not available, but you toggle the execute of the MqttPublish() function block.

The Done can show true and no error, this means the data will be forwarded to the Send() buffer of the operating system.

Once the connection is back on the connection was not closed from the Mqtt Broker, all telegrams will be send from the Send() buffer to the Mqtt Broker and the data will be stored in the database. If a database is used.
BUT: If the Keepalive time (input at MqttConnect()) is over, the connection will be closed and all buffers are cleared.

This means if the Keepalive time is over and the connection is closed. If after the close of the connection, the internet connections returns, the data from the PLC will not send to the broker, because the connection was closed and the buffers (send buffer) will be cleared.

If the Keepalive time is set to a high time, it could happen, that the data will be send once, the connection to the internet returns.

The Send buffer of the V3 PLC is ~160KByte. This value contains not only raw data, it contains also header of Mqtt telegram and maybe other telegrams they are used in the project.

So, we cannot confirm how many data can be buffered in the send buffer.

Also, important: Timeouts from the different clients are important. Once a connection is closed, the buffer is cleared.

So, you can never be sure, that the connection will continue after a defined keepalive time.

### 2.4.12 If data is stored with timestamp (data during the disconnection).

How the system will do the priority for data transfer for current data and old data (data from disconnection time).

This must be programmed by you.

There is no buffer or function that provides this feature.
2.5 Services in the Cloud

2.5.1 What normal settings / knowledge is needed for customer to store / view data on cloud?

We are using Azure. There you need an IoT Hub. This is more or less a gateway/buffer. Then you can use directly a Streaming Analytics service. This service read the data from the IoT Hub and send the data via a SQL query to:
- Power BI (for visualization)
- MS SQL database (for storage)

Of course, there are also other services where you can show the data on a dashboard.

We have created an application example and some additional information's:
- Application Example AC500 MQTT & MS Azure - First steps and configuration
- Application Example AC500 MQTT & Mosquitto - First steps and configuration

Example overall data flow and Architecture

2.5.2 What is the hardware infrastructure like type/capacity of servers etc. required for building an on-premise cloud infrastructure?

This cannot be answered by us. We will provide only the Mqtt functionality and the hardware. The cloud hardware and software are not our part.

2.5.3 What are the licenses /subscriptions required of the Azure software’s?

Please check with Azure support what licenses and subscriptions are required. For playing around, Azure is providing a free account.

2.5.4 What Edge services are required?

There is no Edge device required. You can connect with the AC500 PLC and the Mqtt library directly to the Mqtt broker.

2.5.5 Does Azure support QoS?

Please have a look at this link:
Azure IoT Hub does not support QoS 2 messages.
When a device app publishes a message with QoS 2, IoT Hub closes the network connection.

2.5.6 Does Azure support multiple connections with the same device?
Please have a look at this link:
https://docs.microsoft.com/de-de/azure/iot-hub/iot-hub-mqtt-support

Azure IoT Hub only supports one active MQTT connection per device. Each new MQTT connection for the same device ID causes the IoT Hub to delete the existing connection.

2.5.7 Does Azure support Retain flag?
Please have a look at this link:
https://docs.microsoft.com/de-de/azure/iot-hub/iot-hub-mqtt-support

IoT Hub does not persist retention messages. When a device sends a message with the RETAIN flag set to 1, IoT Hub adds the application property x-opt,retain to the message. In this case, IoT Hub does not persist the retention message, but passes it on to the back-end app.

2.5.8 How to configure the services in the cloud?
Generally, there are multiple ways how to configure your cloud. It totally depends on the use case and underlying requirements.

We have created an application example and some additional information's:
- Application Example AC500 MQTT & MS Azure - First steps and configuration
- Application Example AC500 MQTT & Mosquito - First steps and configuration

Basically, the system looks like this:

With the IoT Hub you can connect edge devices to MS Azure. It is possible to connect devices from different locations to one IoT Hub. Typically, all data received in the hub are forwarded to a standardized endpoint in the IoT Hub. From that endpoint other services like Stream Analytics can access the arriving data.
You could also implement rules for message routing based on message properties (e.g. device id) and create customized endpoints.

Stream Analytics processes the messages that are received by the selected IoT Hub endpoint. You can e.g. select specific values from your message and forward them to other services (e.g. a SQL-database table for storage or Power BI for direct visualization).

Here an example of a Stream Analytics query:

```sql
/*
 * Take the data from the IoT hub and forward all this data to the SQL database
 * We add two hours to the UTC time and save them as a new column named EventProcessedEnqueuedTime and EventProcessedTime
 */

SELECT EventProcessedEnqueuedTime, EventProcessedTime, 2 * EventProcessedEnqueuedTime AS EventProcessedTime,
       Tid, Tdp, Tmp,
       utc,
       ServiceId, ServiceName,
       ServiceId, ServiceName,
       EventProcessedEnqueuedTime, EventProcessedTime
FROM Intrusion
```

- **Line 1:** `/*` - Indicates the start of a comment block.
- **Line 1:** `*` - Indicates the end of a comment block.
- **Line 3-4:** `/* Take the data from the IoT hub and forward all this data to the SQL database */` - Comment that includes the query explanation.
- **Line 5:** `SELECT` - Starts a new SQL selection statement.
- **Line 6:** `EventProcessedEnqueuedTime, EventProcessedTime, 2 * EventProcessedEnqueuedTime AS EventProcessedTime` - Selects the necessary columns from the intrusion dataset.
- **Lines 7-9:** `Tid, Tdp, Tmp, utc, ServiceId, ServiceName, EventProcessedEnqueuedTime, EventProcessedTime` - Selects specific values from the message and forwards them to other services.

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**Definitions:**
- **/* */**: Indicates comment blocks.
- **SELECT**: Begins SQL selection statements.
- **AS**: Indicates an alias for a column.
- **FROM**: Indicates the table from which to select data.
- **WHERE**: Indicates criteria for selecting specific rows.

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**Note:** The above query is a simplified example and may need adjustments based on specific requirements and data structures.
2.6 Reference Solutions

2.6.1 References of AC500 MQTT solutions?

We have a few customers who are already using our AC500 PLCs (V2 and V3) to sending data to the Azure Cloud. We have also a dashboard running on a Azure server, where we send real measured data to the Cloud: https://dashboard.ac500.abb.com/