FDT2 Based Flow Configuration Software on IIoT Environment

Akio Ito * and Jason Sin Wai Chan **

Abstract: This paper presents flow configuration software enhancement on the industrial internet of things (IIoT) environment using field device tool (FDT) ver. 2 (FDT2) technology. The focus of this paper is to exhibit how FDT2 business logic components are preserved for IIoT enhancement and how easily IIoT environment is realized. We show the value of this development by explaining the effectiveness of IIoT use cases. The FDT IIoT server (FITS) and the reference architecture model Industrie 4.0 (RAMI 4.0) relation analysis is done to prove its effectiveness. We confirmed a dramatic change of field device management work by each use case analysis which covers a variety of end-user requirement. Decoupling the DTM user interface and DTM business logic means that digital data produced in DTM business logic is transformed appropriately according to each end-user scenario. We decoupled flow measurement application extended functionality, and it means that achievement in developing key technologies for an asset management tool that makes full use of IIoT to measure mass flow.

Key Words: flow configuration, device integration, industrial internet of things, Industrie 4.0.

1. Introduction

We accomplished the enhancement of our flow configuration software for the industrial internet of things (IIoT) environment using field device tool (FDT) ver. 2 (FDT2) technology. FDT is an international standard and software interface technology which integrates host system and field devices in an industrial control system (ICS) for management purpose, e.g., configuration, monitoring, etc. FDT2 is the latest version of FDT which has an ability of IIoT enhancement [1]. This software is used to configure flow parameter to a multivariable transmitter which is implemented in an ICS in process automation plant.

The FDT Group is proposing an FDT IIoT server (FITS) concept based on FDT2 for adopting IIoT [2]. There are three features in the FITS concept, which are web service, open platform communications (OPC) unified architecture (UA), and control. OPC is the interoperability standard for the secure and reliable exchange of data in the industrial automation space. OPC UA is a platform independent service-oriented architecture [3]. FITS is aimed to preserve the FDT2 device type manager (DTM) business logic which is usually the biggest piece of software components.

In this paper, our target of IIoT meaning is the dramatic change of field device management work which is implemented in an ICS by integrating the latest IT technology. One famous example of IIoT is Industrie 4.0 which uses the reference architecture model Industrie 4.0 (RAMI 4.0) based on system design methodology [4].

The detailed development of the software using FDT2 components is reported in SICE2017 paper [5]. The focus of this paper is to exhibit how FDT2 business logic components are preserved for IIoT enhancement and how easily IIoT environment is realized. We show the value of this development by explaining the effectiveness of IIoT use cases. Three axes analysis of FITS and RAMI 4.0 is done to prove its effectiveness by showing a dramatic change of field device management work which covers a variety of end-user requirement.

2. Previous Work

2.1 Flow Configuration Software

We have been developing our flow configuration software, FlowNavigator EJXMVTool 1, for many years. We will explain previous work related to this development. FlowNavigator EJXMVTool configures flow application information to a multivariable transmitter, EJX910 [6]. EJX910 measures differential pressure (DP), static pressure (SP), and external temperature (ET) and calculates mass flow rate inside the device (Fig. 1).

Fig. 1 Dynamic primary element compensation.

---

1 “EJX”, “FlowNavigator” and “EJXMVTool” are registered trademark or trademarks of Yokogawa Electric Corporation. Any company’s names and product names mentioned in this paper are trade names, trademarks or registered trademarks of their respective companies.
EJXMVTool consists of two modules; flow configuration wizard (FCW) and obtain flow coefficient (OFC). FCW configures flow application information which consists of a primary device and fluid type related with physical property database (Fig. 2). OFC obtains flow calculation values in the device based on sensor data or simulated data and show the value on a graphic user interface (GUI) and saves the data as a log file.

2.2 Flow Configuration Software Implemented on FDT Environment

Then we developed FlowNavigator EJXMVTool using the FDT standard. By using the FDT standard, extended functionalities of flow measurement application are achieved while keeping the interoperability with a host system (Fig. 3) [7],[8]. This is because the FDT interface is defined between a host system (FDT frame application) and a device type manager (DTM). A DTM can be developed freely by device vendors, and any functionality can be implemented. By these features, flow measurement of devices can be configured and achieves high accuracy with securing an end-user for freedom of selecting any field device from any vendor for any FDT host system.

Benefits of flow calculation inside the device with the DTM system to an end-user are shown below [9],[10].

(1) Compared to a controller with flow calculation, the same accuracy is achieved with high response.

(2) Compared to flow measurement of a device without a DTM, high accuracy measurement is possible.

3. Enhancement for IIoT Using FDT2

With advancing technology, it is inevitable for us to consider the possibility of also providing applications, for end-users, which can execute not only on standalone workstations but also on web browsers or even mobile applications via Ethernet, Wi-Fi, 4G Long-Term Evolution (LTE), etc.

Also, we can think of executing functionalities automatically from machines without operations from human beings. This means that sensor data may be processed automatically and transmitted to the upper system effectively. In this sense, integration with OPC UA is required. Sensor data will be processed not only inside a controller located in a plant floor but also in an edge/fog computer located inside a plant floor, and in a cloud computer located outside a plant floor.

The FDT Group is proposing the FITS concept with three features of web service, OPC UA and, control for adopting IIoT [2]. The FITS concept is aimed to protect the investment of vendors and is aimed to preserve the FDT2 DTM business logic (Fig. 4), which is usually the biggest piece of software components.

For IIoT enhancement, we developed our flow configuration software in FDT2. Figure 4 shows that the business logic of the software is easily fitted into an IIoT environment.

3.1 FDT2

FDT is based on two main concepts: frame application and device type managers (DTMs).

Frame application is the runtime environment for DTMs and provides interfaces which enable DTMs to interact with their environment. DTMs, on the other hand, provide device-specific data and functionalities [11].

FDT specification has been upgraded from FDT1.2 to FDT2. Besides technology upgrade, FDT2 has enhanced some of the FDT1.2 concepts, such as decoupling the DTM user interface and DTM business logic. Using a standard messaging interface, a DTM can transport DTM-specific messages and events via the frame application [11], which makes it possible for DTMs to be executing not only on a single frame application, but also on a client-server frame application, where the DTM user interface is executed on a client process of the frame application and DTM business logic is executed on a server process of the frame application. This was not possible during the FDT1.2 era.
Figure 5 illustrates the concept of decoupling the DTM user interface and DTM business logic. Figure 6 illustrates the concept of communication with an associated device.

3.2 Flow Configuration Software on FDT2

Figure 7 illustrates the actual implementation of our flow configuration software on an FDT2 system [12]. We give a name FlowNavigator here in Fig. 7 for the flow configuration software which was explained in Fig. 3 as a flow measurement application with extended functionalities.

Also, we call device DTM (device management) in Fig. 7 for basic device management functionality inside EJX910 device DTM. This means a combination of device DTM (device management) and FlowNavigator works as EJX910 device DTM on FDT Frame application environment as explained in Fig. 3. We have a freedom of developing FlowNavigator functionality inside EJX910 device DTM secured by the FDT interface. FlowNavigator in Fig. 8 is also implemented as part of “DYF (SoftDL) device DTM” [9].

Detail of FlowNavigator is shown in Fig. 7. It consists of EJXMVTool (GUI) and FlowNavigator resource. FlowNavigator resource consists of physical property database and flow calculation logic. Flow calculation logic consists of flow application information with the primary device and fluid type. This means FlowNavigator resource corresponds to flow configuration functionality for multivariable transmitter EJX910 explained in Fig. 2. EJXMVTool (GUI) only works as a user interface of FlowNavigator resource.

Then our idea is to use the FDT2’s enhanced feature for our FlowNavigator EJXMVTool application. EJXMVTool (GUI) and FlowNavigator resource are decoupled between the DTM user interface and DTM business logic (Fig. 7). The resource implemented as DTM business logic is the functionality of flow configuration, and this means the configuration functionality (Fig. 2) is decoupled from the DTM user interface.

4. How FDT2 Developed Components Are Preserved for IIoT Enhancement

In this chapter, how FDT2 developed components are preserved for IIoT enhancement showing the design of our flow configuration software implemented on the FDT2 system. FDT2 defines the general FDT object implementation model as shown in Fig. 8. DTM functions can be with or without user interfaces, depending on the requirements of the functions. If user interfaces are required, they will be implemented in the DTM user interface assembly(s). Based on the above, the implementation of our flow configuration software is shown in the following subsections (Fig. 9).

4.1 Basic DTM

We give a name a Basic DTM here in Fig. 9 for EJX910 device DTM as explained in Fig. 3.

The first step was to design and implement a basic DTM which can perform the following minimum requirements:

i) communicating to a device

ii) saving/loading its data to/from the Frame application’s persistence storage

From the ‘FDT2 Technology’ block of Fig. 9, [A] The DTM Function is a component on the DTM user interface which implements the FDT interface to interact with a user interface of a frame application, via which, messages
are sent to the DTM business logic to process the actual operation.

[B] The message processor receives requests from DTM functions and processes the actual operations.

[C] The data manager is responsible for data persistence of the DTM. It saves/loads data to/from the frame application, which provides actual physical storage.

[D] The communication manager is responsible for reading and writing data to the device by creating communication data requests based on the corresponding device type and protocol.

4.2 Flow Configuration Software EJXMVTool as Plug-gable Advanced Function

We will discuss the design of flow configuration software EJXMVTool as a pluggable advanced function. EJXMVTool is pluggable because our design allows the software function to be implemented without modifying the basic DTM functionalities, using Yokogawa’s proprietary interface, which is a great advantage to allow future extension and easy maintenance.

From the ‘Technology independent Advanced Function’ block of Fig. 9,

[E] The EJXMVTool user control displays various configuration parameters which are required for flow coefficient pre-calculation for, e.g., primary element selection.

[F] The EJXMVTool Controller passes the message to the EJXMVTool business logic for the actual operation via DTM user interface.

[G] The EJXMVTool business logic performs FCW flow configuration and OFC obtain flow coefficient main functionality.

[H] EJXMVTool data manager stores the configuration and flow parameters in DTM in the dataset provided by the frame application, so that even after EJXMVTool User Interface is closed, the configuration and flow parameters are not discarded.

[I] EJXMVTool communication manager obtains flow calculation values, based on sensor data or simulated data.

[J] Physical property database contains physical property information related to flowing fluid, e.g., density and viscosity.

[K] EJXMVTool log file stores obtains flow calculation values, based on sensor data or simulated data.

The following processes describe the general steps of performing flow calculation. Arrows describe the order of processes.

1) Pre-calculate flow coefficient

   The result of the user’s selection [E] is passed to the EJXMVTool business logic [G] for pre-calculation of flow coefficient.

   [E] → [F] → [A] → [B] → [G]

2) Use physical property database

   Physical property database [J] is used by EJXMVTool flow configuration algorithm [G] to perform pre-calculation of flow coefficient.

   [G] → [J]

3) Store configuration and flow parameters

   After the pre-calculation of the flow coefficients and the user applies the values, the EJXMVTool data manager [H] stores the flow parameters.

   [G] → [H] → [C]

4) Write flow parameters to device

   The calculated flow parameters are written to EJX910 as device parameters. Depending on the bus protocol of the device, the communication manager [D] sends corresponding requests to the module in the communication channel, which then writes modified device parameter values to the device via the fieldbus interface.

   The module in the communication channel is unaware on the contents of the requests; its responsibility is only to provide message transfer to the device via the fieldbus interface.

   [C] → [D]
5) Obtain Flow Coefficient

The result of the user’s selection [E] is passed to the EJXMVTool business logic [G], providing the function to obtain flow calculation values [I] and saves them to a log file [K].

[E] → [F] → [A] → [B] → [G] → [I] → [D] → [I] → [G] → [K]

4.3 Developed Components Preserved for IIoT Enhancement

Flow configuration functionality is mainly conducted using business logic, and by preserving the existing business logic, we can enhance the application for IIoT just by implementing different kinds of user interfaces, which can either be executed on web browsers or even mobile applications, fulfilling thin client concept. Also, we can enhance the application for IIoT just by business logic without a user interface like mapping to OPC UA. So, decoupling the business logic and the user interface is an effective approach regarding realizing IIoT.

Referring to the current design, as shown in Fig. 9, we have already decoupled the business logic and user interface aspects of our flow configuration software. This has made it easier for us to integrate our software to IIoT such as FITS, where we expect minimal modifications will be needed to integrate with FITS and with the introduction of a mobile or web client application, an end-user will be able to perform configuration using different platforms. Operating from OPC UA via an upper hierarchy level such as manufacturing execution systems (MES) or enterprise resource planning (ERP) packages without a DTM user interface is also possible.

5. Flow Configuration Software IIoT Use Cases

Figure 10 shows the decoupled DTM user interface and DTM business logic implemented on an FDT2 client and server system connected remotely by network.

FDT2 business logic is easily re-used as a FITS server for IIoT enhancement. The FITS server has the possibility of three features, Web, OPC UA, and Control. We will explain the benefits of FCW and OFC operations in plant floor’s flow configuration work using FITS, and we can show the value of this development through proving the effectiveness of IIoT use cases.

Decoupling the DTM user interface and DTM business logic means that digital data produced in the DTM business logic is transformed appropriately according to each end-user scenario. We decoupled flow measurement application extended functionality, and it means that achievement in developing key technologies for an asset management tool that makes full use of IIoT to measure mass flow.

The main achievement of this development is as below.

1) Users can monitor the status of their instruments on a smartphone or an Ethernet-enabled device from anywhere in a plant and at any time.

2) Compatibility between the FDT2 and OPC UA industrial standards allows the integration of FlowNavigator data with data from manufacturing execution systems (MES), enterprise resource planning (ERP) packages, and other software.

We will show each use case in Fig. 11 and Table 1. These target applications are categorized to asset management and required data access time interval is not so critical. Process Value (PV) parameters needs to be accessed periodically per seconds which network performance allows. But some parameters can be only accessed per minutes, hours, or days for maintenance purpose.

5.1 FITS Web Feature

Combined to Web feature, flow configuration business logic can be executed remotely by any web interface, e.g., browsers, apps, and web sockets with secure interfaces, which is shown as U4 in Fig. 11.

This indicates that configuration (FCW/OFC) and monitoring (OFC) operation is possible from anywhere in the plant.
Fig. 11 Flow configuration software IIoT use cases.

Table 1 Flow configuration software IIoT use cases.

| #  | Use Case Meaning                                                                 | IIoT Benefit                                                                 |
|----|-------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| U1 | Automatic dynamic configuration change during the plant operation (e.g., natural gas compound ratio changes for density calculation) | 1) Low cost and easy to use flow device compared to controller with flow calculation |
| U2 | EJX910 multivariable transmitter flow calculation simulation in cyber space      | 1) Plant planning phase: Simulating flow rate in cyber space contribute improving the plant construction management  
2) Plant service and maintenance phase: Ideal OFC flow measurement value in cyber space will help finding hardware or software problem in EJX910 physical space |
| U3 | OPC UA feature                                                                  | 1) Flow configuration business logic information for enterprise information exchange, e.g., MES and ERP packages  
2) FCW/OFC in DTM and OPC UA together construct Asset Administration Schell (AAS) in I4.0 component |
| U4 | Flow configuration business logic can be executed remotely                     | 1) Configuration (FCW/OFC) and monitoring (OFC) operation is possible from anywhere in the plant using Web interfaces  
2) Physical property database can be installed only inside servers, and management work of DTM client software will be much easier.  
3) Flow configuration business logic can be executed in a fog and cloud environment, and a user only purchases the license without doing installation work |

Physical property database can be installed only inside the server, and management work of DTM client software will be much easier. This is the case when the client can be mobile applications and there is no requirement of software management work for using client software. This will reduce educational cost about software environment in configuration work. Previously each client computer requires software management work of physical property database which is too difficult for end users.
5.2 FITS Control Feature

Combined to Control feature, flow configuration business logic can be executed automatically by any fieldbus connectivity and in a fog and cloud environment, which is also shown as U4 in Fig. 11. This is easily enhanced from FDT’s specific nested communication feature. This means DTM can be placed in cloud outside plant floor where the device is connected to a high-speed network, and a user only purchases the license without doing installation work. This means a user can concentrate on flow configuration application work itself. Security is guaranteed using Virtual Private Network (VPN) communication DTM in such case. Message Queuing Telemetry Transport (MQTT) protocol is also applied using corresponding communication DTM. An FDT control feature can be anytime integrated into new emerging control technology. This means flow configuration application work can be integrated into IIoT technology, and that leads to user benefit.

Flow configuration without user interfaces can be executed inside DTM business logic automatically, which is shown as U1 in Fig. 11. This enables automatic dynamic configuration change during the plant operation which was previously only possible by flow computer.

E.g., The American Gas Association Report No. 8 (AGA8) is used for the natural gas density calculation. AGA8 detail method requires natural gas compound ratio and typically the ratio varies dynamically during the flow measurement. To achieve more accurate flow measurement, updating the compound ratio is required. In such case, automatic ratio update per hours or days using network-connected gas composition analyzer without human being is possible by DTM business logic without user interface.

A flow computer requires programming efforts and comparing to this, more opportunity of a low cost and easy-to-use flow device can be provided to end users. This offers the opportunity of using flow measurement with lower cost.

OFC generates sensor data value into log file. It can be saved on the server and can be accessed from any client and upper layer system, which is shown in U4 in Fig. 11.

This means flow measurement log data which is required for quality assurance, and custody transfer can be provided, which was previously only possible by a flow computer. Checking the flow measurement log using a mobile device in anywhere, the quality assurance work will be easier and reduce the plant management work. The example of OFC custody transfer log item is such as flow rate, accumulated flow rate of days/months, differential pressure, static pressure, temperature, primary element diameter, discharge coefficient, gas expansion factor, Reynolds number, density, compressibility factor, and viscosity. These data are used for management and not time critical data like control.

5.3 FITS OPC UA Feature

Combined to OPC UA feature, flow configuration business logic information without user interface can be used for enterprise information exchange, e.g., MES and ERP packages, which is shown as U3 in Fig. 11. The OFC custody transfer log is uploaded to the enterprise level. OPC UA is noticed as an important technology for Industrie 4.0. Detail discussion follows combined with RAMI 4.0 in the next section. In this case, the shared data by OPC UA is for management use and not time critical data for control.

6. Flow Configuration Software RAMI 4.0 Analysis

Relation analysis of our flow configuration software and one of famous reference architecture RAMI 4.0 [4] are shown in Figs. 12 and 13. RAMI 4.0 defines three axes;
The background of RAMI 4.0 is understood that reference model is created to design a whole industry system optimally using system design methodology. The latest end-user requirement for plant operation varies a lot - e.g., environment requirement and life cycle requirement. Relation analysis of our flow configuration software and RAMI 4.0 helps adjust the asset management of the flow measurement system to a variety of end-user requirement. The following additional use cases are obtained through analysis and dramatically fit to a variety of each end-user requirement.

6.1 IT Layers Axis

Regarding IT layers, the FDT group is proposing that DTM is taking the role of an integration layer which bridges between an asset layer and a communication layer as indicated in Fig. 12. FCW/OFC functionality is designed without the difference of host integration technology and communication protocols and provides unified integration layer environment to a user. Also OPC UA takes the role of an information layer. Then the device information managed in FCW/OFC is used in the information layer on OPC UA environment. This information is base information for the upper layer, the functional/business layer. In this sense, FCW/OFC in DTM and OPC UA together construct Asset Administration Schell (AAS) in I4.0 component [13],[14].

This means FCW/OFC flow device information can be used in the enterprise level via OPC UA through the information layer to the business layer and provides many benefits not only high flow accuracy device as an asset layer. This use case is shown in U3 in Fig. 11.

6.2 Value Stream Axis

One of FCW/OFC information layer example is that FCW/OFC offline configuration functionality inside DTM is treated as cyberspace operation and the operation may be extended to offline plant design phase regarding the value stream lifecycle axis.

One example is that simulating flow rate in cyberspace will help to evaluate plant functionality from early phase and contributes to improving the plant construction management. Because flow parameter is not user visible, flow calculation simulation using EJX910 in physical space is necessary to confirm the flow parameter correctness during plant commissioning work. If we can use EJX910 in cyberspace, the confirmation work is possible from the plant design phase. This will reduce efforts during plant commissioning, and correct parameters are obtained during the plan design phase.

Moreover, from the service and maintenance phase, ideal OFC flow measurement value in cyberspace helps to find hardware or software problems in physical space. The usual use case of flow measurement value confirmation is done by one point data referring primary element sizing data. OFC flow measurement value of cyberspace and physical space can be compared by any given point. This increases the safety feature of flow measurement application. This use case is shown in U2 in Fig. 11.

6.3 Hierarchy Levels Axis

As already explained, automatic dynamic configuration change during the plant operation by flow configuration without user interfaces and OFC sensor data monitoring features extend the functionality previously possible by a flow computer. This means extension is made from the field device level to the control device level regarding the hierarchy levels axis.

7. Conclusion

We have implemented differential pressure based flow configuration software using the latest FDT2 technology. FDT2 developed components are preserved for IIoT enhancement, and the business logic of the software will be easily fitted into the IIoT environment like FITS. Decoupling the DTM user interface and DTM business logic means that digital data produced in the DTM business logic is transformed appropriately according to each end-user scenario. We decoupled flow measurement application extended functionality, and it means that achievement in developing key technologies for an asset management tool that makes full use of IIoT to measure mass flow.

We have made IIoT benefit analysis using RAMI 4.0 three axes to prove the effectiveness of this development. Because the RAMI 4.0 reference model uses system design methodology and it helps us to analyze our target ICS system optimally, we confirmed a dramatical change of field device management work by each use case analysis which covers a variety of end-user requirement. The effectiveness of flow calculation simulation in cyberspace varies from the plant planning phase and the plant service and maintenance phase. There are a lot of benefits of flow configuration business logic executed remotely and flow configuration business logic information can be used for enterprise information exchange, e.g., MES and ERP packages. FCW/OFC in DTM and OPC UA together construct AAS in I4.0 component.

We will further continue extending our flow configuration software for IIoT environment and bring more benefits to ICS plant floor operation.

References

[1] FDT Website, https://fdtgroup.org/
[2] A. Ito: FDT standardization and industrial system integration technology, Proc. SICE the 4th Multi-symposium on Control Systems (MSCS 2017), pp. 2E1-3, 2017 (in Japanese).
[3] OPC foundation Website, https://opcfoundation.org/
[4] P. Adolphs: RAMI 4.0 An architectural model for Industrie 4.0,
A. Ito and J.S.W. Chan: Flow configuration software implemented on FDT2 standard, *Proc. SICE Annual Conference 2017*, pp. 617–623, 2017.

A. Ito, S. Mimura, E. Koyama, T. Odohira, M. Nikkuni, and T. Miyauchi: EJX910 multivariable transmitter, *Yokogawa Technical Report*, No. 42, pp. 13–16, 2006.

A. Ito: Device configuration software development on EDDL and FDT/DTM environment, *Proc. SICE Annual Conference 2008*, pp. 929–932, 2008.

A. Ito: Extending field device functionality using FDT/DTM technology, *Proc. SICE Annual Conference 2010*, pp. 716–720, 2010.

A. Ito, E. Koyama, and T. Kawano: Compressibility compensation calculation of mass flow measurement device using FDT conform configuration software, *Proc. SICE Annual Conference 2011*, pp. 106–110, 2011.

A. Ito, M. Nakagawa, Y. Suzuki, and E. Koyama: Dynamic primary element compensation for differential pressure flow device using FDT conform configuration software, *Proc. SICE Annual Conference 2012*, pp. 1701–1705, 2012.

T. Takeuchi: General information of FDT2 and FDI, *Proc. SICE Annual Conference 2015*, pp. 1149–1155, 2015.

FSA120 Flow Configuration Software, User’s Manual, IM 01C25R51-01E, Yokogawa Electric Corporation, 2015.

Structure of the administration shell, http://www.plattform-i40.de/I40/Redaktion/EN/Downloads/Publikation/structure-of-the-administration-shell.pdf?__blob=publicationFile&v=5

Industrie 4.0 Plug-and-produce for adaptable factories: Example use case definition, models, and implementation, https://www.plattform-i40.de/PI40/Redaktion/EN/Downloads/Publikation/Industrie-40-Plug-and-Produce.pdf?__blob=publicationFile&v=3

**Akio Ito** (Member)

He graduated from the University of Tokyo in 1983 before joining Yokogawa Electric Corporation. His interests are in sensors and industrial communication.

**Jason Sin Wai Chan**

He graduated from Nanyang Technological University of Singapore in 2008 and received a Bachelor Degree in Computer Engineering before joining Yokogawa Engineering Asia. He also received the Masters Degree in Knowledge Engineering from National University of Singapore in 2013. His interests are in sensors and industrial communication.