WHITEPAPER

Enabling the Army's Tactical Microgrid Standard — MIL-STD-3071

As modern weapon systems are being rapidly deployed at the tactical edge, the need to provide reliable, cost-effective power to the warfighter is more critical than ever. Providing power at the tactical edge can be challenging.

When establishing a Forward Operating Base (FOB) for example, power must initially come from advance vehicles and then seamlessly transition to available power sources as the base becomes operational. It must dynamically right-size as troops and platoons come and go, allowing dynamic assignment of power to the most critical base needs — and it must do so while an adversary actively tries to disrupt it.

The Army's Tactical Microgrid Standard (TMS), MIL-STD-3071, is designed to meet these challenges. In short, TMS defines a distributed power system, including power sources, loads, distribution, and management systems. TMS does this by letting platoons bring in and carry out the power they need, while letting the base commander allocate available power to the base's most critical needs. The modular, distributed architecture of TMS means an adversary can degrade power by hitting specific sources, but will have extreme difficulty knocking it out.

RTI Connext® has supported Smart Microgrids and Distributed Energy Resources for years — it provides the performance, security, and reliability needed to run these systems [1] [2]. For this reason, TMS highlights the Data Distribution Service (DDS®) standard as the core protocol to provide command and control between these distributed components.

Further, Connext is DoW Technical Readiness Level (TRL)-9 proven, making it the ideal solution for TMS.

The Advantage of a Distributed Microgrid vs. a Centralized Power System

A distributed modular system offers the following three core advantages over a centralized system.

- **Resiliency:** As a distributed architecture with multiple smaller components working together as a unified power grid, microgrids eliminate single points of failure. The system may degrade, but it can dynamically adapt to meet the most critical needs. Resilience is especially desirable for a FOB, where many distributed, small-footprint power sources make it harder for the adversary to knock out power to the base.
- **Flexibility:** With clean energy alternatives and EVs, microgrids provide flexibility, enabling many energy sources and loads to adapt to a common power infrastructure. While clean energy is unlikely to be a priority on the battlefield, flexible power sources let the FOB start with truck-based Auxiliary Power Units (APUs) and then transition to other sources as they arrive, allowing the truck to move on to its next assignment.
- **Elasticity:** The distributed nature and "smart," semi-automated control of the Tactical Microgrid both allow platoons to bring in and take out the power they need, while letting the base commander direct power to the base's most critical needs.

By creating the TMS MIL-STD-3071[3], the Army has defined not only a standard microgrid architecture and associated components, but also a common data model to monitor, command, and control the Tactical Microgrid (TMG). In addition, TMS prescribes the data flows and well-defined Quality of Service (QoS) profiles assigned to each flow. The TMS standard will be discussed in more detail below, but defining a standard across all component types of the microgrid enables multivendor interoperability with ease of use for the Warfighter. Simply put, TMS provides the Warfighter with simple-to-use, best-of-breed multi-vendor power components on the battlefield.

SCOPE of MIL-STD-3071

The Army standard states: "MIL-STD-3071 establishes the communication and control interface requirements to enable TMG components to operate as a single entity to provide electricity in a tactical environment. TMS defines the component interfaces of the hardware and software necessary to provide intelligent control, power quality, electrical stability, electrical performance, personnel safety, security, and protection[3]." The scope of MIL-STD -3071 is displayed in the diagram below.

The left side of the diagram shows the six primary components making up a TMG that TMS is required to monitor and/or control (i.e., make "intelligent"). The right side shows the general

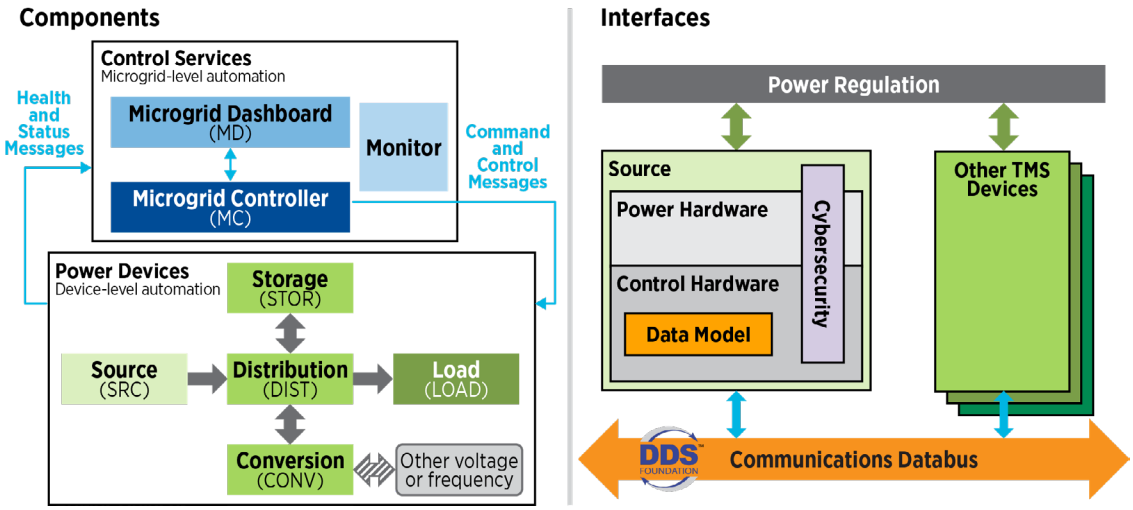


Figure 1: TMS Architecture

architecture of TMS Control Hardware and Interfaces for any one component. TMS is fundamentally a software specification. While TMS identifies the hardware components of the TMG, it does not define the hardware design of any of these components, or the Control Hardware associated with making the component intelligent.

Standards related to the physical interconnection and safety of any TMG or other power component is beyond the scope of TMS.

Ensuring Interoperability by Standardizing the What, Who, and How of the System

A key aspect of TMS is the utilization of DDS as the communications bus to orchestrate this dynamic power environment.

TMS utilizes DDS to ensure real-time, distributed data-centric control while providing interoperability. DDS explicitly enables the three core attributes of Resiliency, Flexibility, and Elasticity as described above, while meeting U.S. Department of War (DoW) requirements as defined in the Modular Open Systems Approach (MOSA) principles[4].

While the security aspects of TMS are mentioned, as of this writing, the details of how to provide security are not specified. The DDS standard has a companion security standard[5] called DDS-Security™, which defines how security can be integrated directly into DDS communications. The security standard supports encryption, access control, and authentication. RTI Connext has deployed DoW systems with military-grade security, utilizing standards-based encryption and authentication for the DDS Databus.

WHAT

A key part of MIL-STD-3071 is the Data Model, which includes about 37 topics defined in IDL (Interface Definition Language) format. IDL is "compiled" by DDS tools to create serializers and deserializers for a given platform, where the language binding, operating system, and CPU architecture define the platform. The serializers and deserializers normalize the data sent and received over the DDS Databus so components on different platforms can interoperate. For efficiency, data is transmitted over the wire in binary form. DDS uses a Discovery Process that pairs writers and readers for individual dataflows, matching data types and compatible QoS settings. During

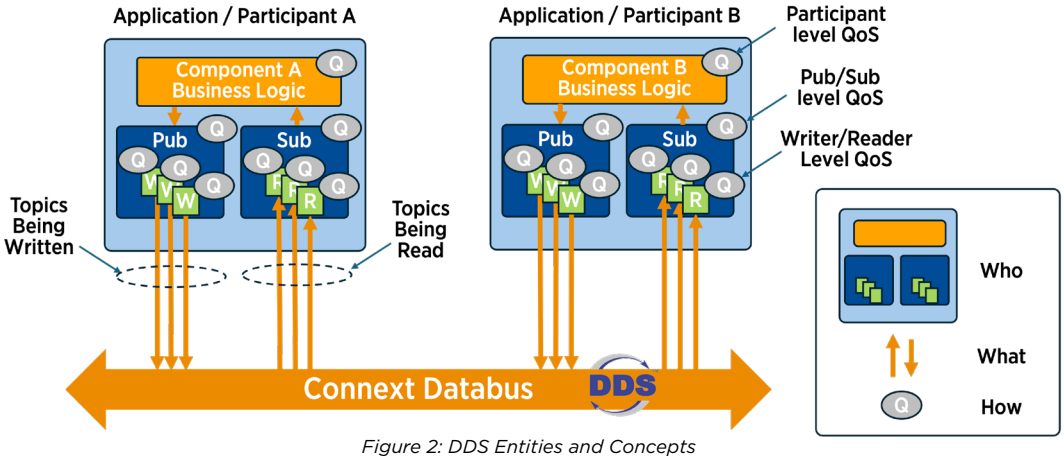


Figure 2: DDS Entities and Concepts

the Discovery phase, the topic structure (referred to as the Type Object) is sent and validated for pairwise consistency. From the Application point of view, it simply includes the generated serializers and deserializers for the topics it requires. It can read and write from the DDS databus to send and receive the data it needs. For each component, TMS specifies which topics it requires and how it interacts with other components. From a DDS software perspective, the topics make up the "What" of the system. The topics represent the data flows, the 'what' that is communicated on the DDS databus between components to monitor and/or control them.

TMS uses the concept of DDS Instances to identify individual devices. As part of the IDL, a key ('Fingerprint' or Unique device Identity field) is defined to identify a specific instance of a device. A DDS Instance allows DDS to allocate memory and organize samples in individual caches per Instance or device (Similar to Key'd Rows in a database). Using instances in TMS offers many benefits. The most important ones are 1) flexibility; different TMG components can come and go without disrupting the system, and 2) data-centricity- the receivers can filter on keys so that the application programmer can be certain that all messages received are intended for this application.

WHO

Each TMS component is required to have a software application (in DDS terminology, a Domain Participant) with the logic to monitor and/or control the component. In DDS, each Participant has Publishers and Subscribers that instantiate Readers and Writers. Each Reader or Writer is used to read or write one topic. TMS defines many topics to monitor and/or control a given component. From a DDS perspective, these components, along with their topic writers and readers, make up the "Who" of the system. That is, the "Who" sends and receives these topics.

TMS defines seven types of equipment that may be a part of a TMG.

- **Type I – Power Generation Sources:** This includes generators, solar panels, and other energy sources.
- **Type II – Energy Storage Systems:** Batteries and other storage devices store excess energy and provide backup power.
- **Type III + IV – Feeder & Distribution Systems:** Feeder and Distribution Systems go hand-in-hand and are called out as part of the "Distribution" equipment. They are often depicted as a single block in TMG diagrams. Technically, the Feeder Systems form the TMG structure while the Distribution Systems carry power from the Feeder Systems to the load.

  Feeder Systems establish the power and communications bus for the TMG. They accept power from Type 1 Power Sources and Type II Energy Storage and interconnect them to the Type IV Distribution System. They interface with the Type V Control Systems to manage, meter, and monitor circuits.

  Distribution Systems provide cabling and receptacles for the loads with circuit protection and circuit management functions as required by Type V Control Systems.
- **Type V – Control Systems (Control Services):** The Control Systems provide power management and monitoring for the TMG. They enable fault handling and power flow throughout the TMG as provisioned by the human operator. Note that the Control Services include one or more Microgrid Controllers, Microgrid Dashboards, and Microgrid Monitors.

  These are defined in the spec as follows:

  - Microgrid Controller (MC) – Coordinates automation across the microgrid. Monitors power devices and requests actions or other configuration settings as needed.
  - Microgrid Dashboard (MD) – Provides a microgrid-level graphical user interface (GUI) to monitor health and status. May allow the operator to send requests to the MC for execution.
  - Monitor (MON) – Provides passive monitoring of all communications. Does not send any information. May be used to record network traffic, create logs, and monitor test capability.
- **Type VI – Loads:** Loads consume power. They comprise "Standard Loads" and "Smart Loads," with the distinction that "Smart Loads" allow for the control and monitoring of their operations.
- **Type VII – Power Conversion:** Power Conversion Systems enable Type I Power Sources and Type II Energy Storage Systems, which produce different voltages and/or are Direct Current (DC), to connect to the TMG feeder bus.

HOW

TMS defines eight QoS profiles and associates one profile with each of the 36 topics.

1. **PublishLast:** Used for topics with an "At Start" or "On Change" data trigger. Provides reliable delivery of the most recent sample, even if the subscriber joins after the data was published.
2. **Command:** Used for topics with an "As Needed" data trigger. Provides reliable delivery of the most recent sample, only to subscribers who join before the data is published. DDS tracks sent data and acknowledgements, resending as needed to ensure delivery.
3. **Response:** Used for topics with a "Within 0.1 s" data trigger. Provides the same performance as the Command profile, ensuring that requests and replies exhibit the same behavior.
4. **Reply:** Used for the Reply topic. Provides performance the same as the Response profile, except the history is increased to support replies from multiple request topics. For example, increasing the history to 128 means the reader's cache memory is allocated to hold 128 samples.

5. **Continuous:** Used for topics with a "Periodic 0.1 s" data trigger. Provides best-effort delivery of each sample, with a 2-second delivery deadline. Also known as Best Effort QoS.
6. **Medium:** Used for topics with a "Periodic 1s" data trigger. Provides best-effort delivery of each sample, with a 3-second delivery deadline.
7. **Slow:** Used for topics with a "Periodic 10s" data trigger. Provides best-effort delivery of each sample, with a 20-second delivery deadline.
8. **Rare:** Used for topics with a "Periodic 900s" data trigger. Provides best-effort delivery of each sample, with a 2,000-second delivery deadline.

To support redundant controllers and stability during controller startup and potential restarts, TMS also specifies that all topics use Exclusive Ownership QoS (vs. Shared Ownership). Exclusive Ownership allows two writers to write the same sample; DDS passes the sample with the 'strongest' (highest value) ownership strength to the application.

These QoS profiles and attributes ensure that data is provided from a producer to a consumer in a compatible way. For example, if status monitoring is supposed to be provided at a specific rate, the writer must be able to meet the reader's request (i.e., even if the writer can write faster, as long as the reader requests something equal to or less, they match). During Discovery, DDS negotiates (Request / Offer or RxO) the requested rate.

Together, these QoS profiles define "The How" that each message or topic is to be delivered between components.

TMS Level Data Flow Patterns

Above the DDS QoS Level, TMS also defines three basic data flow patterns used between devices for all of the topics: Status, Request/Response, and Custom.

In many cases, topics are related, and in all cases, topic data flow patterns are clearly outlined in tables that show the interaction across all components. A more complicated example, shown in figure 3, is the AuthorizedToEngergize topic; it has three interacting topics: AuthorizationToEngergizeRequest, AuthorizationToEngergizeReply, and AuthorizationToEngergizeResult.

STATUS: With the Status data flow pattern, data is sent from the Power Device to a Controller Service either periodically at one of the four rate profiles defined by TMS or aperiodically based upon a change in status using the On Change data profile. An On Change profile can trigger if the unit is manually operated and the status changes, or if a controller commands a change. Figure 3 shows the Status Data Flow Pattern.

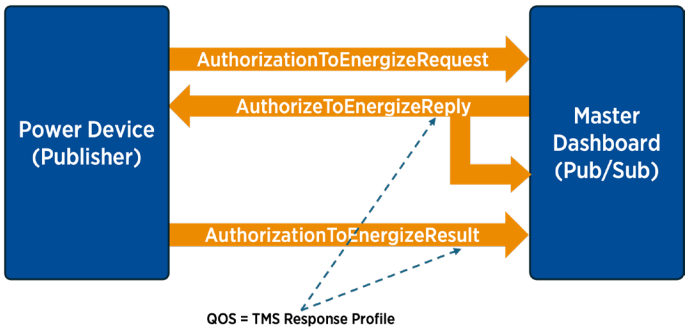


Figure 3: Status Data Flow Pattern

REQUEST / RESPONSE: In the Request/Response data pattern, a Device (in the example below, the Master Controller) requests something from the Power Device. The Power Device provides a Response based on the details TMS calls out for each specific request topic. As a result of the request, a change may occur and needs to be sent to the Master Dashboard (or Monitor function).

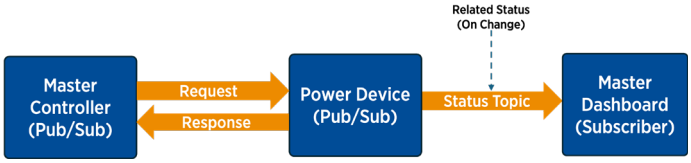


Figure 4: Request, Response w/related On Change Status update

CUSTOM: Uses the Custom Data flow pattern when the flow requires something different from the Status or Request/Response flows. Below is an example of the AuthorizationToEnergize Request. This might be initiated when the device is connected to the TMG and manually placed 'online.' Here, the operator at the Master Dashboard sees the request and approves the authorization, enabling the reply. The feedback path for the reply is used when the dashboard logic sending the reply is not in the same controller as the dashboard logic tracking activity. Once authorization is approved, the Power Device then sends a Result. Note: TMS specifies that, for this topic, both the Reply and Result use the Response QoS profile.

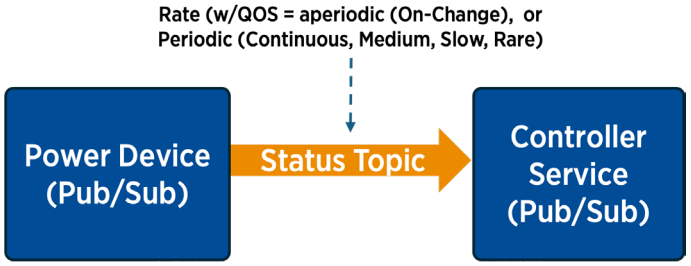


Figure 5: Example Custom Data Flow Pattern

Adapting Existing Equipment to TMS

Many vendors interested in TMS compliance already sell DoW non-TMS power equipment that meets all non-TMS DoW standards for connectivity and safety. These components typically use a proprietary intelligent control system, often a Controller Area Network (CAN) bus with a proprietary command set. A "quick-fix" to adapt this equipment to TMS is to "front-end" the existing device with an industrial-grade off-the-shelf controller, such as an inexpensive BeagleBone Black Industrial Processor module. The front-end processing module adapts the TMS topics from the TMG to its internal protocol.

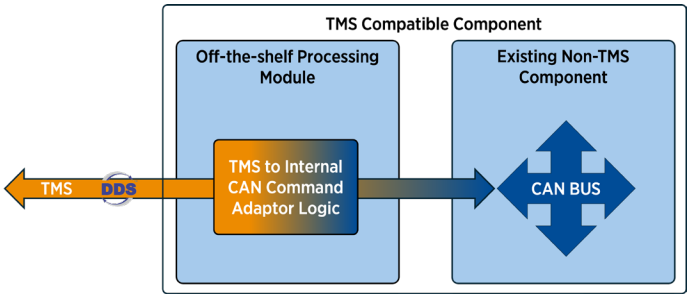


Figure 6: Example of Adapter from non-TMS to TMS Component

Beyond the Standard

Connext not only delivers one of the industry's most proven and trusted DDS implementations, but also offers out-of-the-box tools and capabilities that save critical time for developers. Examples include a DDS databus introspection tool — RTI's Admin Console (also integrated with Connext Studio, a VS Code plugin for one-stop development); Record and Replay services, which provide in-lab and production after-action analysis of system operation; and RTI Routing service, which supports system scaling and protocol adapters (e.g., connection to CAN bus, etc.).

For developers interested in AI, RTI offers Connext AI, which uses RTI's industry-leading documentation to answer natural-language questions and even write code for you via the RT MCP (Mode Context Protocol) server. RTI also offers secure off-board WAN connectivity for remote command and control and telemetry.

RTI Connext is battle-tested and proven at Technology Readiness Level 9 (TRL 9). Combined with its comprehensive development environment, advanced debugging tools, expert support, and the option of RTI Professional Services for hands-on development consultation, Connext provides a proven, cost-effective DDS solution for the Army's TMS components.

Conclusion

MIL-STD-3071, a.k.a. TMS, ensures interoperability between "intelligent components" (with DDS applications created on different platforms, from different vendors), providing distributed, scalable power to Forward Operating Bases in austere environments.

By using DDS as the communications databus, TMS meets microgrid requirements for Resiliency, Flexibility, and Elasticity in a tactical environment, while adding standardization for multi-vendor support, interoperability, and ease of use for the Warfighter.

References

[1] RTI Whitepaper: How To Gain Visibility and Collaborative Control over Distributed Energy Resources (DERs)

[2] RTI Microgrid Case+Code

[3] MIL-STD-3071 Tactical Microgrid Standard (TMS)

[4] Modular Open Systems Approach (MOSA): Treating Data as a Strategic Resource Through Data Centricity

[5] DDS Security Standard

ABOUT RTI

RTI is the real-time data streaming company for intelligent distributed systems. RTI Connext® software is the critical nervous system for over 2,000 designs across Aerospace and Defense, MedTech, Automotive, and Robotics.

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