Field Management System White Paper

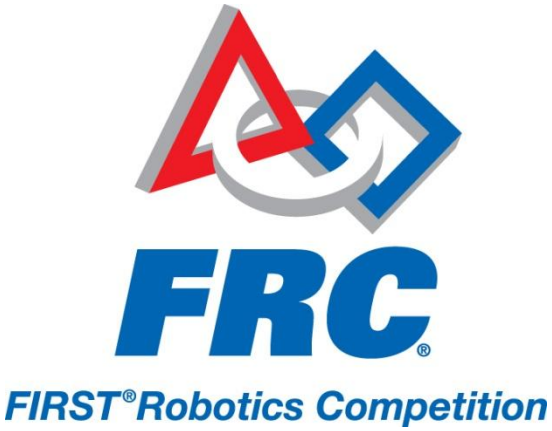


Table of Contents

Overview....2
Driver Station <–> Robot Communications – The Basics....2
On-Field Communications Path for a Single Team....3
Frequently Asked Questions....4
- Does FMS control the robot?....4
- What does the flashing Player Station light mean?....4
- What information does FMS log?....4
- Can one team's DS control another team's Robot?....4
- What happens when you plug your DS into the playing field?....5
- Is Practice Mode on the DS different from FMS mode?....5
- Why do I need to press F1 when a joystick is disconnected in FMS Mode?....5
- Is there anything different about the practice field vs. the playing field?....6
- Are there any bandwidth limits on the playing field?....6
- Are there any Quality of Service (QoS) priorities on the playing field?....6
- Which network ports are open on the playing field?....6

Overview

The Field Management System (FMS) is the electronics core of a *FIRST* Robotics Competition (FRC) playing field. It encompasses all the controls for the field electronics, team robots, and is used to manage the event by creating match schedules, managing all field hardware during a match (timers, team lights, estops, etc.), scoring the matches in real-time, posting information to the Audience screen, and uploading results data to the Internet.

FMS is based on Ethernet architecture. Components such as the Driver Station or the touchscreens used by the referees integrate with FMS through direct wired Ethernet interfaces. Devices like the ball counters used in Breakaway and Rebound Rumble, or the Estops and Stack Lights mounted in each Player Station, interface through Ethernet-based Input/Output (I/O) modules that are donated to *FIRST* by Rockwell Automation. The lights used to illuminate the tower bases in Logomotion and the bridges in Rebound Rumble are controlled via Ethernet-enabled power supplies donated to *FIRST* by Philips Color Kinetics.

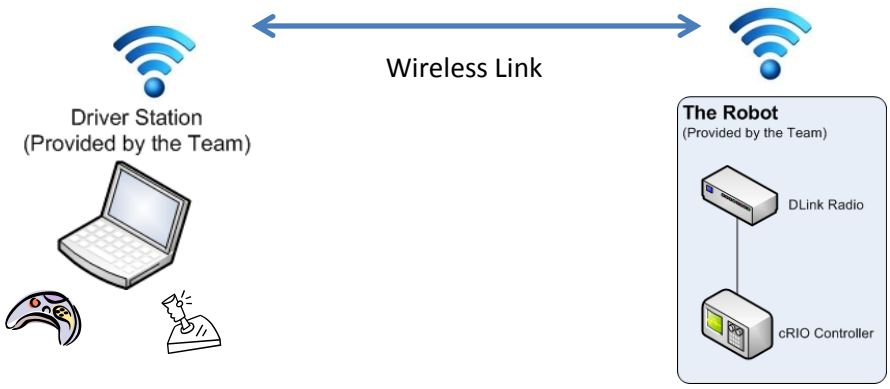
This white paper focuses on the electronics infrastructure needed to control the robots on the playing field. Specific details on the FMS software used during each season can be found in the Field Management System User Guide, publically available on the FRC Scorekeeper Forum.

Frequently Asked Questions about the Field Management System appear at the end of this document.

This document was written using the 2012 FRC Robot Control System and Field Management System as the model platform, however with only minor differences, this system topology has remained the same since 2009.

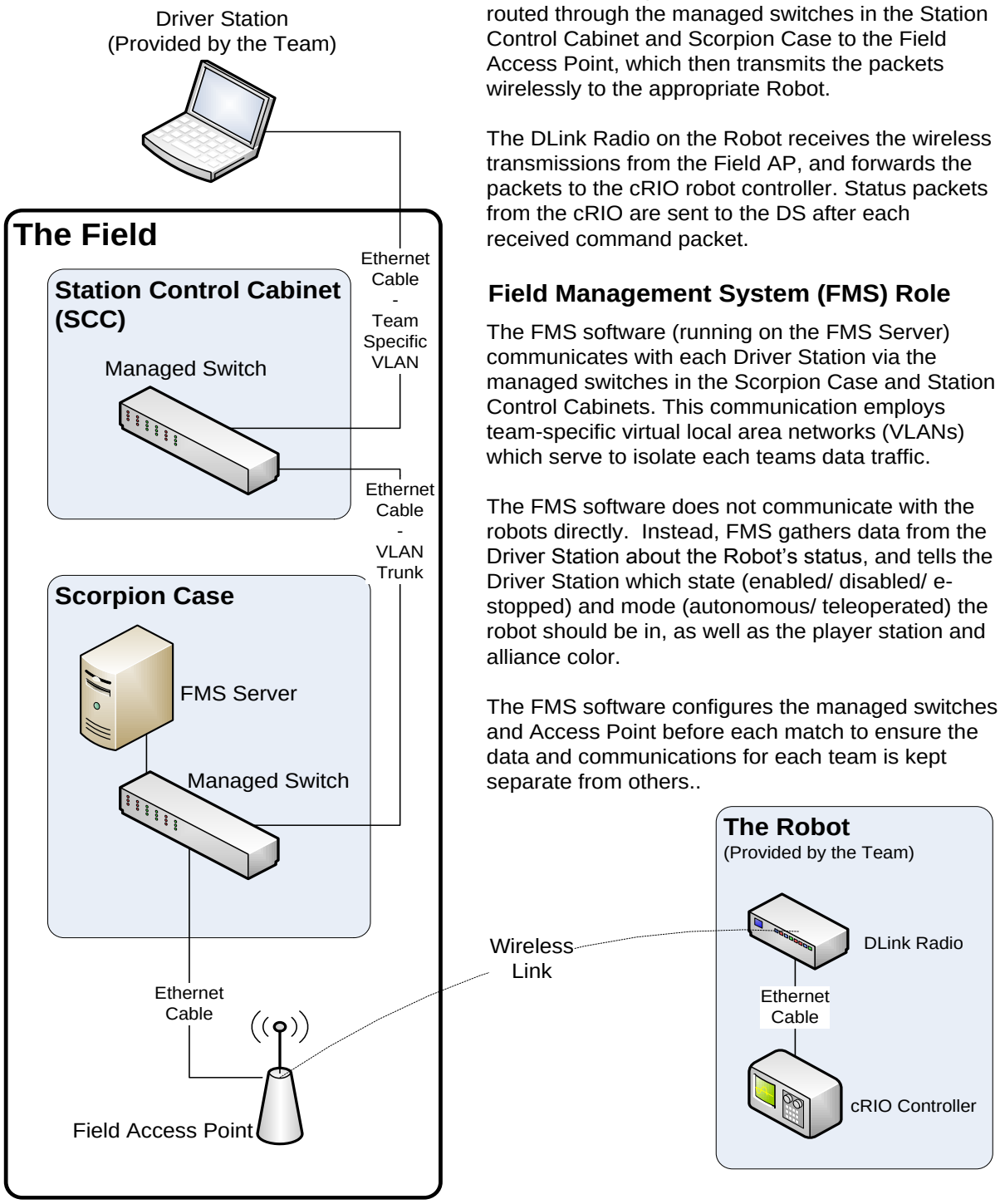
Driver Station <–> Robot Communications – The Basics

The standard configuration for controlling an FRC robot is two core components, the robot itself with a cRIO controller installed, and a netbook/ ultrabook/ laptop etc. running the FRC Driver Station (DS) software. The FRC Robot Control System is built such that the DS is the master controller, i.e. the status and actions of the robot are determined by commands from the DS.



Communication packets from the DS are broadcast wirelessly via the integrated radio in the DS or a separate radio (like the WRT610N provided in previous seasons), or through a tether (i.e wired Ethernet.) The DLink radio on the Robot receives the command packets from the DS and forwards them to the cRIO robot controller. Status packets from the cRIO are sent to the DS after each received command packet.

On-Field Communications Path for a Single Team



Driver Station – Robot Communications

Communication packets from a Driver Station are routed through the managed switches in the Station Control Cabinet and Scorpion Case to the Field Access Point, which then transmits the packets wirelessly to the appropriate Robot.

The DLink Radio on the Robot receives the wireless transmissions from the Field AP, and forwards the packets to the cRIO robot controller. Status packets from the cRIO are sent to the DS after each received command packet.

Field Management System (FMS) Role

The FMS software (running on the FMS Server) communicates with each Driver Station via the managed switches in the Scorpion Case and Station Control Cabinets. This communication employs team-specific virtual local area networks (VLANs) which serve to isolate each teams data traffic.

The FMS software does not communicate with the robots directly. Instead, FMS gathers data from the Driver Station about the Robot's status, and tells the Driver Station which state (enabled/ disabled/ e-stopped) and mode (autonomous/ teleoperated) the robot should be in, as well as the player station and alliance color.

The FMS software configures the managed switches and Access Point before each match to ensure the data and communications for each team is kept separate from others..

Frequently Asked Questions

Does FMS control the robot?

No, FMS does not communicate with the Robots directly. On the playing field, FMS communicates exclusively with each DS, sending it commands for enable/disable, auto/teleop, Estop, player station number and alliance color. The DS then sends this data to the Robot.

What does the flashing Player Station light mean?

The flashing light in the Player Station indicates that FMS does not think your DS has a connection to your robot. There are two main ways for this condition to occur: the DS is not communicating with FMS, or the DS is telling FMS it cannot communicate with the robot.

What information does FMS log?

FMS combines the status data from each DS along with the data that is monitored from the field components and stores this data in log files. The following data is logged every 500ms for each of the six robots on the playing field during each match:

- Timestamp (local time)
- Match Number
- Team Number
- Match Time
- Alliance
- Mode (Auto/Teleop)
- DS in FMS Mode (yes/no)
- Robot Mode (enable/disable)
- Estop state (on/off)
- Robot Link
- Average packet trip time between DS and Robot
- Number of missed packets between DS and Robot
- Total number of packets sent by DS to Robot
- Robot Battery Voltage
- Blue SCC connected (yes/no)
- Red SCC connected (yes/no)
- Blue Scoring I/O connected (yes/no)
- Red Scoring I/O connected (yes/no)

Can one team's DS control another team's Robot?

The FRC field is configured such that each team has its own virtual local area network (VLAN) within which all data is passed. The characteristics of a VLAN ensure that the command packets from one team's DS do not cause a response on another team's robot. These VLANs exist on both the wired and wireless side of the playing field's network; this is why for example, it's necessary for a team in Blue Player Station #1 to connect their DS into the corresponding cable for that station. On the wireless side of the network, the VLANs are configured in the field access point by broadcasting an individual network (SSID) for each of the six teams on the field, each with its own encryption passkey. These VLANs are configured prior to the start of each match so that only the six teams assigned in FMS may operate on the field.

What happens when you plug your DS into the playing field?

Once the process of setting up all the VLANs on the playing field is complete, through a process FRC calls "match prestart", the FMS starts sending out command packets to the six DS's. When a team plugs their DS into the Ethernet cable for their assigned Player Station, the DS receives these commands packets from FMS and switches over into FMS Mode. It's at this point "FMS Connected" is displayed on the DS "Operation" tab. When in FMS Mode, the DS continues to serve as the master controller for the Robot, but state (enable/disable/estop) and mode (auto/teleop) are dictated by the FMS. The FMS tells the DS what to do, and the DS then tells the Robot.

Is Practice Mode on the DS different from FMS mode?

Yes, the two modes do have some differences, but the majority of the functions are identical. Both operating modes step through the same states, the order is:

1. Autonomous Disable – state prior to match start
2. Autonomous Enable – Autonomous period
3. Autonomous Disable – end of Autonomous period
4. Teleop Disable – end of Autonomous period, prior to start of Teleop period
5. Teleop Enable – Teleop period
6. Teleop Disable – end of Teleop/match end

Joysticks are handled a bit differently between the two modes. In Practice Mode unplugging a joystick will result in the robot being switched to Disabled. This is designed to be a safety feature, as the robot may be running in a variety of environments that might not be equipped with barriers to safely contain the robot.

Unplugging a joystick in FMS Mode will not result in the robot being disabled. If a joystick becomes disconnected, simply plugging it back in will not result in it returning to normal operation. The user must press F1 on the DS to manually rescan the USB interface to redetect the joystick.

Finally, the network port used by the DS to send command packets to the Robot is different in Practice Mode than the one used when in FMS Mode.

Why do I need to press F1 when a joystick is disconnected in FMS Mode?

While in Disable, the DS software periodically polls the USB interface for the presence of devices and adds/removes them from the list of joysticks on the DS "Setup" tab automatically. This polling is only done in Disable as it is computationally expensive and could compromise control of an enabled robot.

In FMS Mode, the DS's Enable/Disable state is dictated by FMS. When a joystick is disconnected during a match the robot is not disabled because FMS is continuously telling the DS to be enabled, and when the DS state is Enable, it does not poll the USB interface for device changes. Pressing F1 on the DS manually rescans the USB interface to redetect the change in joystick devices. If a joystick has disconnected from the DS or is otherwise unresponsive the recommended procedure is:

1. Unplug the joystick device's USB connector from the DS
2. Press F1 – this clears any non-responsive/stale devices from the DS device list (not necessary in 2013)
3. Plug in the joystick device
4. Press F1 to rescan the USB devices

Is there anything different about the practice field vs. the playing field?

Yes. The practice field uses a different field access point, it does not employ the port filtering used on the playing field, nor does it employ VLANs.

Are there any bandwidth limits on the playing field?

Not at this time.

Are there any Quality of Service (QoS) priorities on the playing field?

Not at this time.

Which network ports are open on the playing field?

The ports that the teams are able to access on the playing field are as follows:

- TCP 1180: This port is typically used for camera data from the robot to the DS when the camera is connected to port 2 on the 8-slot cRIO. This port is bidirectional on the field.
- TCP 1735: SmartDashboard, bidirectional
- UDP 1130: Dashboard-to-Robot control data, directional
- UDP 1140: Robot-to-Dashboard status data, directional
- HTTP 80: Camera connected via switch on the robot, bidirectional
- HTTP 443: Camera connected via switch on the robot, bidirectional

All these ports are open on the playing field, so a team can use them as they wish if they do not employ them as outlined above (i.e. TCP 1180 can be used to pass data back and forth between the robot and the DS if the team chooses not to use the camera on port 2 of the 8-slot cRIO)