Washing Machine Control System

Tavish Burnah – CS-6500

Database

Washing Machine Cloud Servers

[See 3]

Detergent Motor Assembly

Wi-Fi Adapter

[See 3]

Control Interface

[See 4]

Central Control Unit
See Detailed Diagram

[See 1]

[See 2]

[See 2]

Pressure Switch

Heater

[See 2]

[See 2]

[See 1]

Water Inlet Valve

Tub
With
Agetators

Door Lock Motor

Temp. Sensor

Particle Sensor

[See 5]

[See 5]

Clarity Sensor

Sensor Controller Unit
See Detailed Diagram

[See 5]

Drive Motor

Disposal Unit

Drain Pump

[See 6]

[See 6]

[See 2]

Motor Control Unit
See Detailed Diagram

Component Key

Sensor

Physical Component

Software Running Component

Motor

Motorized Lock

Pump

Server

Tub

Smart Phone

Component Descriptions

Control Interface
Allows user configuration from the washer itself

Wi-Fi Adapter
Used to connect to the washing machine cloud

Heater
Heats the water for use in the washing and rinsing cycles

Central Control Unit
Contains the primary logic for washing machine control

Pressure Switch
Protects the washing machine from excess pressure

Water Inlet Value
Opens and closes to allow water into the machine

Door Lock Motor
Locks and unlocks the tub door

Temp. Sensor
Reports the water temperature

Particle Sensor
Reports the amount and size of particles in the water

Clarity Sensor
Reports the clarity of the water

Sensor Controller
Handles reading and digitizing all sensor data

Drive Motor
Controls the spin of the Tub

Disposal Unit
Pulverizes any small particles before draining

Drain Pump
Pumps water and to drain the tub

Motor Control Unit
Controls the drive motor, disposal unit and drain pump

Washing Machine Cloud Servers
Servers which all Washing Machine connect to that allow Smart Phones to see status and control the Washing Machines

Connector Descriptions
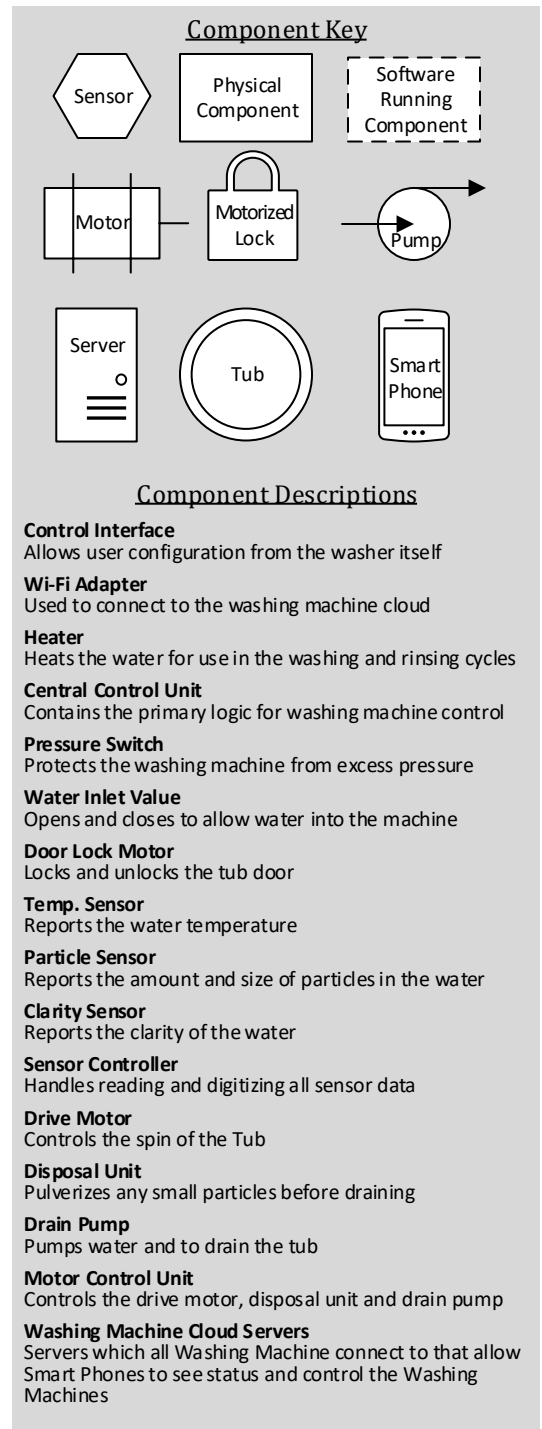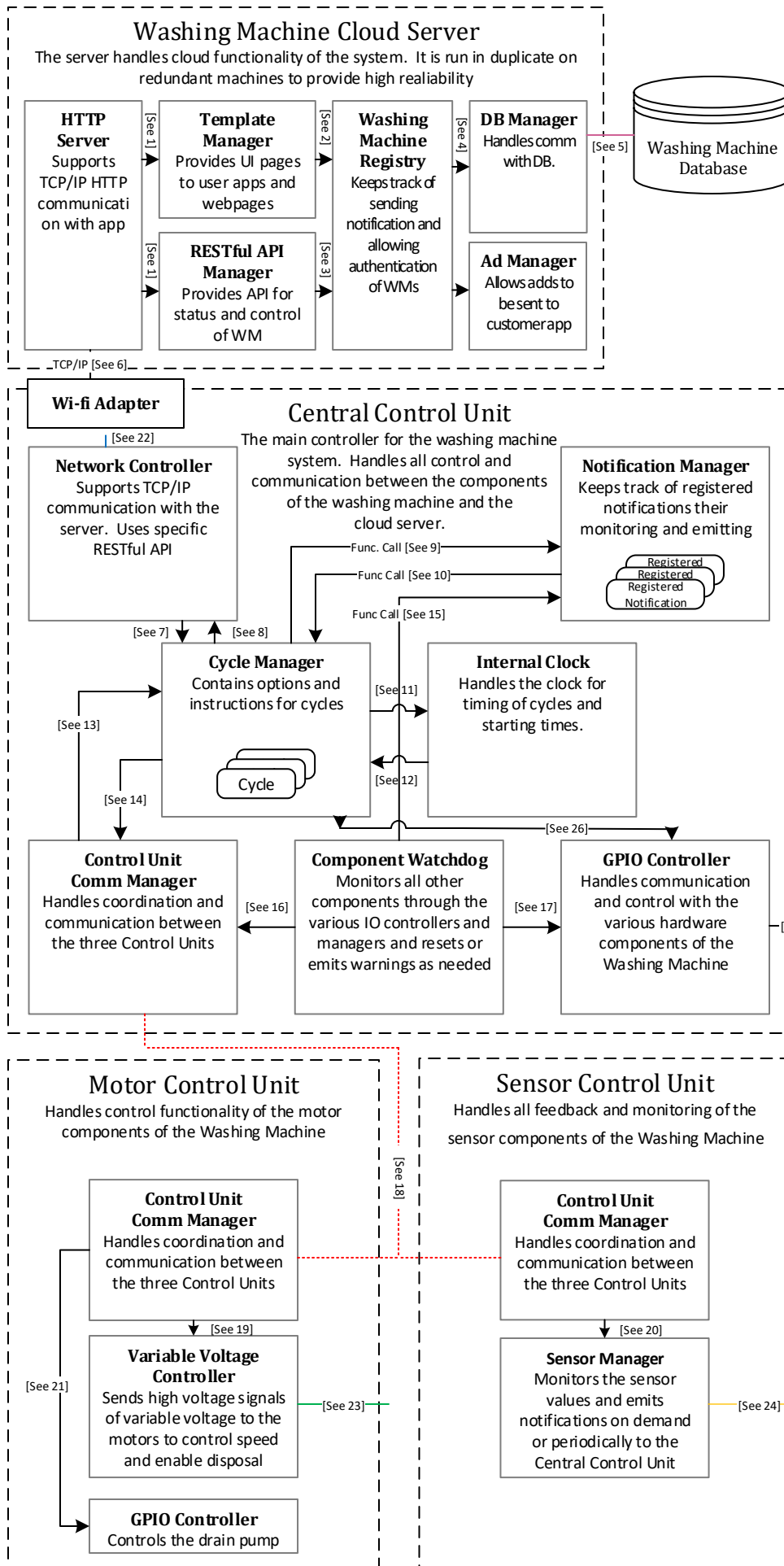
1. The Inter-controller communication bus connects the secondary control components (Motor Control Unit and Sensor Control Unit) to the Central Control Unit. This allows the Central Control Unit to receive status, control and monitor the sub units.

2. The Custom Wiring harness connects the Central Control Unit or the Motor Control Unit to various components using custom wiring configurations as needed.

3. The TCP/IP communication between the Cloud Server and the Smart Devices, and between the Washing Machine and the Cloud Server allows status to be sent to the cloud, and then relayed on to devices. It also allows smart devices to control the Washing Machines. This communication uses RESTful API.

4. The PCI Bus allows the Central Control Unit to communicate over WI-FI through a home router and to the Cloud Server.

5. The Sensor Communication wire allows high-quality analog sensor information to be read by the Sensor Control Unit. This is a polled connection.

6. The High Voltage Analog Control Cable allows the Motor Control Unit to direct the Drive Motor and Disposal Unit by sending variable voltages to the components.

Connector Key

- – – – PCI Bus: High Speed Expansion Bus
- .... Proprietary Inter-Controller Communication Bus
- ——— High Voltage Analog Control Cable
- ——— Sensor Communication Wire
- ——— Custom Wiring Harness
- –·–·– TCP/IP Communication
- ——— Data Access Connector

Washing Machine Control Units
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Washing Machine Cloud Server
The server handles cloud functionality of the system. It is run in duplicate on redundant machines to provide high reailability

HTTP Server
Supports TCP/IP HTTP communication with app

[See 1]

Template Manager
Provides UI pages to user apps and webpages

[See 2]

Washing Machine Registry
Keeps track of sending notification and allowing authentication of WMs

[See 4]

DB Manager
Handles comm with DB.

[See 5]

RESTful API Manager
Provides API for status and control of WM

[See 1]

[See 3]

Ad Manager
Allows adds to be sent to customer app

Washing Machine Database

TCP/IP [See 6]

Central Control Unit
The main controller for the washing machine system. Handles all control and communication between the components of the washing machine and the cloud server.

Wi-fi Adapter

[See 22]

Network Controller
Supports TCP/IP communication with the server. Uses specific RESTful API

Notification Manager
Keeps track of registered notifications their monitoring and emitting

Registered
Registered
Registered
Notification

Func. Call [See 9]

Func Call [See 10]

Func Call [See 15]

[See 7] [See 8]

Cycle Manager
Contains options and instructions for cycles

[See 13]

Cycle

[See 11]

[See 12]

Internal Clock
Handles the clock for timing of cycles and starting times.

[See 14]

Control Unit Comm Manager
Handles coordination and communication between the three Control Units

[See 16]

Component Watchdog
Monitors all other components through the various IO controllers and managers and resets or emits warnings as needed

[See 26]

[See 17]

GPIO Controller
Handles communication and control with the various hardware components of the Washing Machine

[See 25]

Motor Control Unit
Handles control functionality of the motor components of the Washing Machine

Control Unit Comm Manager
Handles coordination and communication between the three Control Units

[See 18]

[See 19]

Variable Voltage Controller
Sends high voltage signals of variable voltage to the motors to control speed and enable disposal

[See 21]

[See 23]

GPIO Controller
Controls the drain pump

Sensor Control Unit
Handles all feedback and monitoring of the sensor components of the Washing Machine

Control Unit Comm Manager
Handles coordination and communication between the three Control Units

[See 20]

Sensor Manager
Monitors the sensor values and emits notifications on demand or periodically to the Central Control Unit

[See 24]

Connector Key
- – – – PCI Bus: High Speed Expansion Bus
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- ——— High Voltage Analog Control Cable
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- ——— Custom Wiring Harness
- –·–·– TCP/IP Communication
- ——— Data Access Connector
- ——▶ Function Call

Connector Descriptions
1. Synchronous Procedure Call invocation notifying the template manager or RESTful API Manager of incoming requests.
2. Synchronous Procedure Calls notifying the registry of an incoming request for control or information.
3. Synchronous Procedure calls notifying the registry of updates from the washing machine.
4. Invocations through procedure calls informing the DB Manager to update data in the database. Requests will be synchronous, but data updates may be asynchronous.
5. Two-Way data access to the Data Management System updating or requesting information.
6. TCP/IP communication through the internet from the Washing Machine. Two-way, synchronous RESTful commands.
7. Synchronous procedure call invocations requesting actions to be performed by the Cycle Manager.
8. Asynchronous procedure call invocations notifying of status updates.
9. Synchronous procedure calls registering data to be notified. The result is the success or failure of the registration.
10. Asynchronous procedure call invocation initiating a notification process.
11. Synchronous procedure call initiating a timed event.
12. Asynchronous Procedure Call callback for timeout of timed event.
13. Invocation of procedure call from other control units requesting data or sending status, asynchronous.
14. Invocation of procedure call to other control units requesting data or starting process, asynchronous.
15. Command from the watchdog to the notification system containing error report or maintenance request.
16. Ping to other control units to determine if up and running.
17. Ping to other components to determine if up and running.
18. Proprietary two-way communication between control units.
19. Synchronous procedure call invocation from Comm. Manager to start controlling high-voltage motors.
20. Synchronous procedure call invocation from Comm. Manager to request sensor status.
21. Synchronous procedure call invocation from Comm. Manager to start pump control.
22. PCI commands, two-way, between network manager and Wi-Fi Adapter to perform network communication.
23. Variable high-voltage signal to motors.
24. Analog sensor signals from various sensors.
25. Proprietary communication to various components using wire harness.
26. Synchronous procedure call invocations from cycle manager to various components.

Washing Machine Process View
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Start Standard Wash Cycle
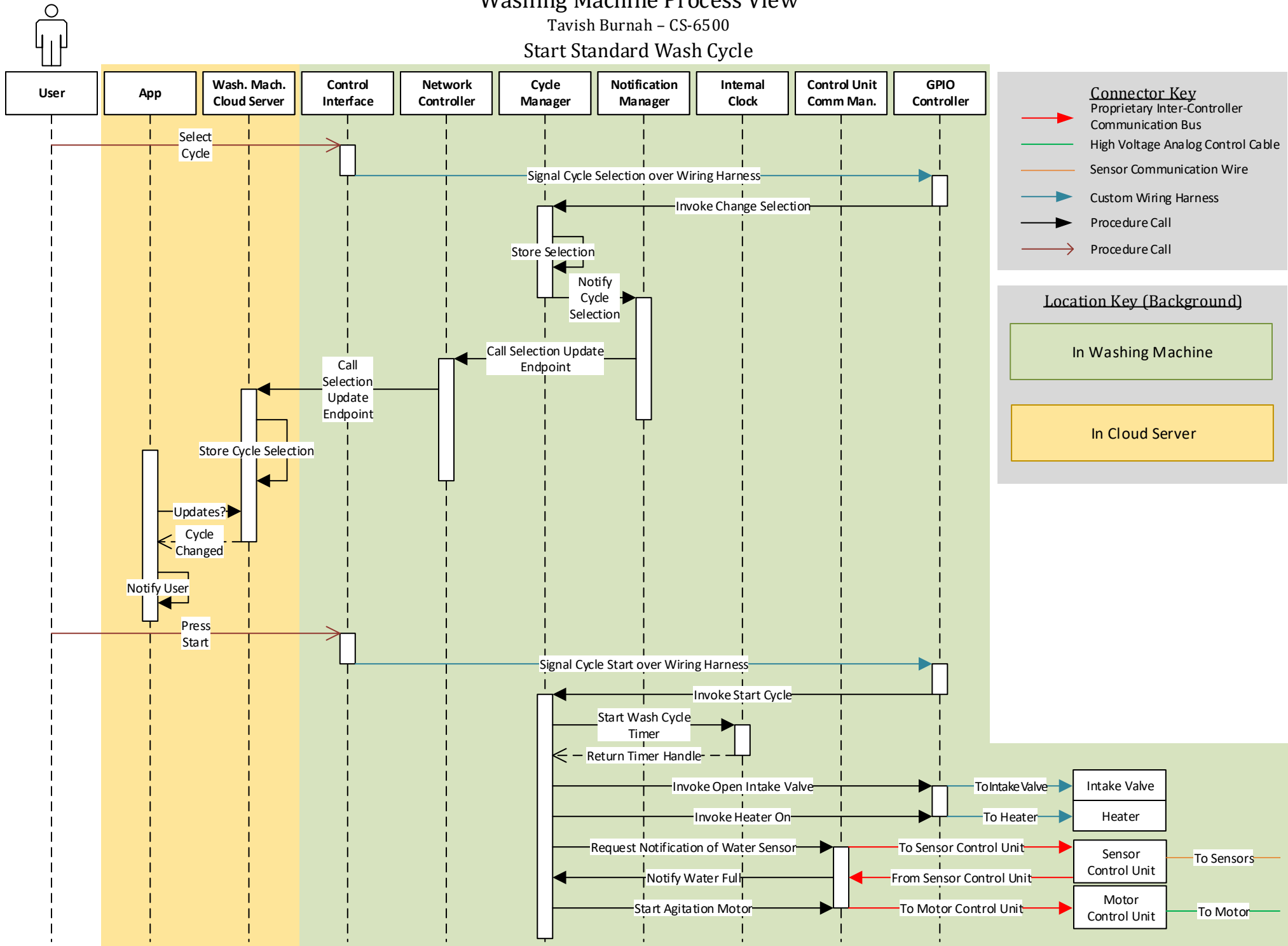
Washing Machine Use Cases

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Machine Starts Cycle !
1. Machine Locks door
2. Machine starts cycle
Variations:
2a. Door is not closed
   Machine beeps warning
   Machine notifies server of abort with reason
   Machine aborts start

Server Starts Cycle !
1. Server sets machine status to Start command
2. Machine requests current status periodically
3. **Machine Starts Cycle**
Variations:
3a. Machine notifies of abort
   Server sends app abort notification

Machine Starts Delayed Cycle !
1. Machine sets timer
2. Machine displayed countdown
Variations:
1a. Existing delay start exists
   Machine beeps warning
   Machine notifies server of abort with reason
   Machine aborts delayed start

Server Starts Delayed Cycle !
1. Server sets machine status to Start command
2. Machine requests current status periodically
3. **Machine Starts Delayed Cycle**
Variations:
3a. Machine notifies of abort
   Server sends app abort notification

Start Cycle from Machine !
1. User **Change Cycle Type** on Control Interface
2. User presses Start button
3. **Machine Starts Cycle**

Start Cycle from App !
1. User Change Cycle Type on Mobile App
2. User presses Start button on App
3. **Server Starts Cycle**

Start Delayed Cycle from App !
1. User Change Cycle Type on Mobile App
2. User chooses delay time
3. User presses Start button on App
4. **Server Starts Delayed Cycle**

Begin Previously Delayed Cycle Immediately !
1. User views dashboard of app
2. App displays existing delayed cycle waiting
3. User selects existing cycle
4. App displays cycle settings
5. Users chooses Start Immediately
6. Server sends Machine Start command

Notify of Cycle Finish !
1. Cycle finishes.
2. Machine sends Server Cycle Finished notification
3. Server sets status of machine to Cycle Finished
4. App background service requests status from server
5. Server returns Cycle Finished status
6. App displays notification to user

Notify of Maintenance Need !
1. Machine Watchdog detects anomaly
2. Machine sends Server Maintenance Need notification
3. Server sets status of machine to Maintenance Needed
4. App background service requests status from server
5. Server returns Maintenance Needed status
6. App displays notification to user

Send Ad to App !
1. Marketing decides to annoy users
2. Marking adds ad to Server
3. Server sets status of machine to show ad
4. App background service requests status from server
5. Server returns ad notification
6. App displays ad notification to user
Login.
3. User is sent to Event List page.
Variations:
3a. Server has 'No Ad' setting for user set
   Server sends marketing interface error

View Remaining Time !
1. User navigates to app dashboard
2. App shows current cycle
3. User clicks on cycle
5. App requests cycle data from Server
6. Server returns cycle data
4. App shows cycle details

Change Cycle Type !
1. User selects cycle type.
2. Machine sets cycle type internally
3. Machine updates interface

Notify of Water Overflow !
1. Machine sensors detects overflow
2. Machine sends Server Overflow notification
3. Server sets status of machine to Overflow
4. App background service requests status from server
5. Server returns Overflow status
6. App displays priority notification to user

Login
1. User opens app
2. App displays login page
3. User enters credentials
4. App sends server credentials
5. Server verifies credentials
6. App displays Dashboard
Variations:
5a. Server cannot validate credentials
   Server returns to app error
   App prompts user to reenter credentials
   Repeat step 5

Washing Machine Use Cases
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For the Washing Machine Control System, the obvious overlying pattern that fit the problem was the Client Server pattern. The functional requirements stated that the machine must connect to a central corporate entity, and be able to serve up advertisements and remote control. This type of system can only be supported using Client-Server. In this case, the client is the phone app, and the server is the Washing-Machine (corporate) Cloud Server. At the same time, the relationship between the Washing Machine itself and the Cloud Server is a Client Server pattern.

Internally repeated several times within the washing machine is the Sense-Compute-Control pattern. This is represented by the various sensors reading data which is fed into the Sensor Control Unit. The Sensor Control Unit then forwards the information on to the Central Control Unit which computes which actions to do next and sends commands to the various components controlling the washing machine.

The Presentation, Abstraction, Control pattern is present in the views presented to the various users. A standard view is presented from the server to users through the phone app. This is served up through the Template Manager. Another view is presented through this same view to the corporate users in order to load advertisements and check on maintenance of washing machines.

The Supreme Commander pattern is visible in the system architecture. The Central Control Unit drives all decisions all other components of the system make and perform. It represents the Supreme Commander of the system. Sub commanders exist in the Sensor Control Unit and Motor Control Unit. All other components are driven directly by the Central Control Unit.

In order to support the reliability of the system, a Component Watchdog exists which monitors all physical components with the system and attempts to address any errors that arise. If an error state cannot be corrected, it then has the ability to notify the home owner and corporate office that maintenance needs to be scheduled.

To allow the Central Control Unit to focus on the large picture, and to contribute to performance, two sub Control Units exist to take on responsibilities that require constant polling or power output. These to control units are the Motor Control Unit and Sensor Control Unit. These all share a common Control Unit Communications Manager which manages all communications between the Control Units. This communication occurs on a Proprietary, RS-485 based protocol.

The system is kept secure through the Washing Machine Registry component of the Cloud Sever. It authenticates all login requests with the appropriate washing machines. Data is never "Pushed" to the physical washing machines. Instead, the machines periodically Poll for commands and information. This adds to the level of security.