# ADVANCED EMBEDDED SOFTWARE DEVELOPMENT
## Project 2 – Multi-controller System

**Nachiket Kelkar** **29th April 2019** **Puneet Bansal**

**TEST PLAN**

1. Control loop

   Description: The sensor data is gathered by the remote node and sent to the controller node. The controller node has the set thresholds for the data for appropriate actuation steps and the logger file which can be viewed for operational status and working condition of the remote node. The controller node takes the decision and send it back to the remote node. The remote node act according to the decision sent by the control node. The test plan includes the data sent successfully, decision made, control message passed to the remote node, remote node acting appropriately.

   Preconditions:
   1. The controller node (beagle bone) and remote node (TM4C1294XL) connected with SPI.
   2. The UART is enabled on remote node and log file open on controller node.
   3. The terminal open to see the results.

   Test Steps and expected result:
   a. The remote node shows the data gathered from the sensor.
   b. The remote node generates the transaction id and source of data and send it to controller node when controller node initiates the SPI transaction and sends request message as 0x01.
   c. The transaction id and source are printed on serial terminal and remote node shows 0x01 command.
   d. The controller node initiates other transaction and sends command 0x02 [DATA REQUEST].
   e. The remote node prints the command and sends the sensor data to the control node. The control node takes decision and send the control message back by initiating other SPI transaction.
   f. The control message is displayed by remote node.

2. Soil moisture sensor and water pump control

   Description: The soil moisture sensor is analog sensor connected to ADC of TIVA board. The soil moisture sensor task wakes up and take the soil moisture readings at periodic intervals. It sends the data value to the inter-board SPI task which transmits the data to control node and to LCD task to display the moisture. The control message received is sent to water pump control task which then runs the water pump with PWM signal with different speeds using different duty cycle based on the control message. The test will test the working of soil moisture task, water pump task, LCD task, inter-process communication of data and sensor and actuator working.

   Precondition:
   1. The soil moisture is connected to the remote node.
   2. The LCD is connected to the remote node.
   3. The controller node is active and remote node is connected to it.
   4. The UART is enabled on remote node and log file open on controller node.
   5. The terminal open to see the results.

Test Steps and expected result:

1) Moisture values less than 500.
   a. The soil moisture sensor is inserted in dry soil.
   b. The LCD shows the readings less than 500.
   c. The data is sent to the control node and control node shows the received data on terminal.
   d. Then the control message (0x0aaa) is sent to remote node which is run water pump with PWM of 100% duty cycle and is displayed on terminal and LCD.

2) Moisture values above 500 and below 1500.
   a. The soil moisture sensor is inserted in damp soil.
   b. The LCD shows readings in between 500 -1500.
   c. The data is sent to the control node and control node shows the received data on terminal.
   d. Then the control message (0x06aa) is sent to remote node which is run water pump with PWM of 60% duty cycle and is displayed on terminal and LCD.

3) Moisture values greater than 2000.
   a. The soil moisture sensor is inserted in moist soil.
   b. The LCD shows readings above 2000.
   c. The data is sent to the control node and control node shows the received data on terminal.
   d. Then the control message (0x00aa) is sent to remote node which is run water pump with PWM of 0% duty cycle i.e. OFF and is displayed on terminal and LCD.

3. SPI temperature sensor and Fan control

Description: The temperature sensor is SPI sensor connected to the SPI pins of the TIVA C series board. The temperature task wakes up periodically and takes the readings from the temperature sensor. It sends the data value to the inter board SPI task which send it to the control node. The control node takes the decision and passes the control message to remote node. The remote node takes the appropriate action of switching On or OFF the temperature controller fan. The data is also displayed on the LCD. This test will verify the working of temperature sensor task, fan task, LCD task, inter process communication of data and sensor and actuators working as expected.

Precondition:

1. The temperature is connected to the remote node.
2. The LCD is connected to the remote node.
3. The controller node is active and remote node is connected to it.
4. The UART is enabled on remote node and log file open on controller node.
5. The terminal open to see the results.

Test Steps and expected result:

1) Temperature values less than 30 Celsius
   a. The temperature sensor reads the values less than 30 Celsius.
   b. The LCD shows the readings less than 30 Celsius.
   c. The data is sent to the control node and the control node shows the received data.
   d. The control message is received from control node and remote node displays it as 0x0055 which is, Fan OFF and the fan status LED (D2 on Tiva) is OFF and status is also displayed on LCD.

2) Temperature values greater than 30 Celsius
   a. The temperature sensor reads the values greater than 30 Celsius.
   b. The LCD shows the readings greater than 30 Celsius.
   c. The data is sent to the control node and the control node shows the received data.
   d. The control message is received from control node and remote node displays it as 0x0055 which is, Fan ON and the fan status LED (D2 on Tiva) is ON and status is also displayed on LCD.

4. Degraded node operation with removed soil moisture sensor
   Description: When the soil moisture sensor is pulled out the remote node should know that the sensor is pulled out also the controller node should realize that the soil sensor is no more present on the remote node. The remote node then should only send the data of temperature and should stop sending the soil moisture readings. The controller node should indicate that it is working in the degraded state. When the sensor is inserted back the remote node must automatically detect it and start taking the readings and sending it to the controller node. The controller node should detect the presence of sensor again. This test can be done to check the working of remote and controller node in degraded state of operation when the soil moisture sensor is removed.

   Preconditions:
   1. Soil moisture sensor is removed, and temperature sensor is hooked up to the remote node.
   2. The LCD is connected to the remote node.
   3. The controller node is active and connected to the remote node.
   4. The UART is enabled on remote node and log file open on controller node.
   5. The terminal open to see the results.

   Test steps and expected result:
   a. Remove the soil moisture sensor.
   b. Log message only shows the readings from the temperature sensor.
   c. The data received by the controller node is only from the temperature sensor.
   d. The remote node terminal messages show the message ‘Soil moisture sensor removed’.
   e. The controller node log messages show ‘Degraded state’.

5. Degraded node operation with removed temperature sensor
   Description: When the temperature sensor is pulled out the remote node should know that the sensor is pulled out also the controller node should realize that the temperature sensor is no more present on the

remote node. The remote node then should only send the data of soil moisture and should stop sending the temperature readings. The controller node should indicate that it is working in the degraded state. When the sensor is inserted back the remote node must automatically detect it and start taking the readings and sending it to the controller node. The controller node should detect the presence of sensor again. This test can be done to check the working of remote and controller node in degraded state of operation when the temperature sensor is removed.

Preconditions:

1. Temperature sensor is removed, and temperature sensor is hooked up to the remote node.
2. The LCD is connected to the remote node.
3. The controller node is active and connected to the remote node.
4. The UART is enabled on remote node and log file open on controller node.
5. The terminal open to see the results.

Test steps and expected result:

a. Remove the temperature sensor.
b. Log message only shows the readings from the soil moisture sensor.
c. The data received by the controller node is only from the soil moisture sensor.
d. The remote node terminal messages show the message 'Temperature sensor removed'.
e. The controller node log messages show 'Degraded state'.

6. Controller node with no connected remote node.

Description: This condition arises if the controller node is connected and the remote node is not powered up or none of the sensors are active on remote node. The controller node in this case should be aware of the absence of the remote node. Once it is concluded that the remote node is inactive, the alert message is logged in the log file.

In order to check the whether the remote node is active or not, a 5 second timer is used. Within this 5 second if a valid new transaction id is received from the remote node, the timer is fed again. However, if no valid transaction id is received within those 5 seconds, this indicates that either both the sensors on the remote node are not active or the remote node is disconnected.

Apart from this, the on-board user LED on pin 55 glows, indicating the absence of control node.

Preconditions:

1. Control node active.
2. Timer configured to trigger every 5 seconds
3. LED pin 55 configured as output
4. Terminal open to see the results

Test steps and expected result:

a) The control node is powered on and code is executed. The remote node is not powered on.
b) The control node starts polling the remote node for new messages and this is displayed on terminal

c) Transaction id's are observed for some period and it is inferred that the Transaction id's remain the same.
d) 5 second timeout occurs, proving absence of remote node. This is displayed on the terminal and logged as an alert to the log file

7. Remote node with no connected controller node.
Description: This condition arises, if the remote is active, however, the control node is not powered up. In such a situation the remote node is expected to work in a degraded state. The degraded state for remote node is acquiring the data from sensors and performing the actuation based on pre-defined thresholds. This test case can be performed to check the operation of remote node in degraded capability.

Preconditions:
1. Remote node active.
2. Sensors configured and operational.
3. Terminal open to see the results

Test steps and expected result:
a) The remote node is active and code running. Control node is not active.
b) The LED D1 on Tiva board glows indicating that controller node is not active.
c) The terminal message shows the sensor data generated.
d) The LCD shows the readings.
e) Cover the temperature sensor so that the temperature crosses 30 Celsius.
f) The LED D2 lights up indicating FAN is ON then cool the sensor so that temperature goes below 30 Celsius.
g) The LED turn OFF indicating the FAN is OFF.

**TEST RESULT**

| TEST | RESULT |
|---|---|
| Control loop | Passed |
| Soil moisture sensor and water pump control | Passed |
| SPI temperature sensor and Fan control | Passed |
| Degraded node operation with removed soil moisture sensor | Passed |
| Degraded node operation with removed temperature sensor | Passed |
| Controller node with no connected remote node. | Passed |
| Remote node with not connected controller node. | Passed |

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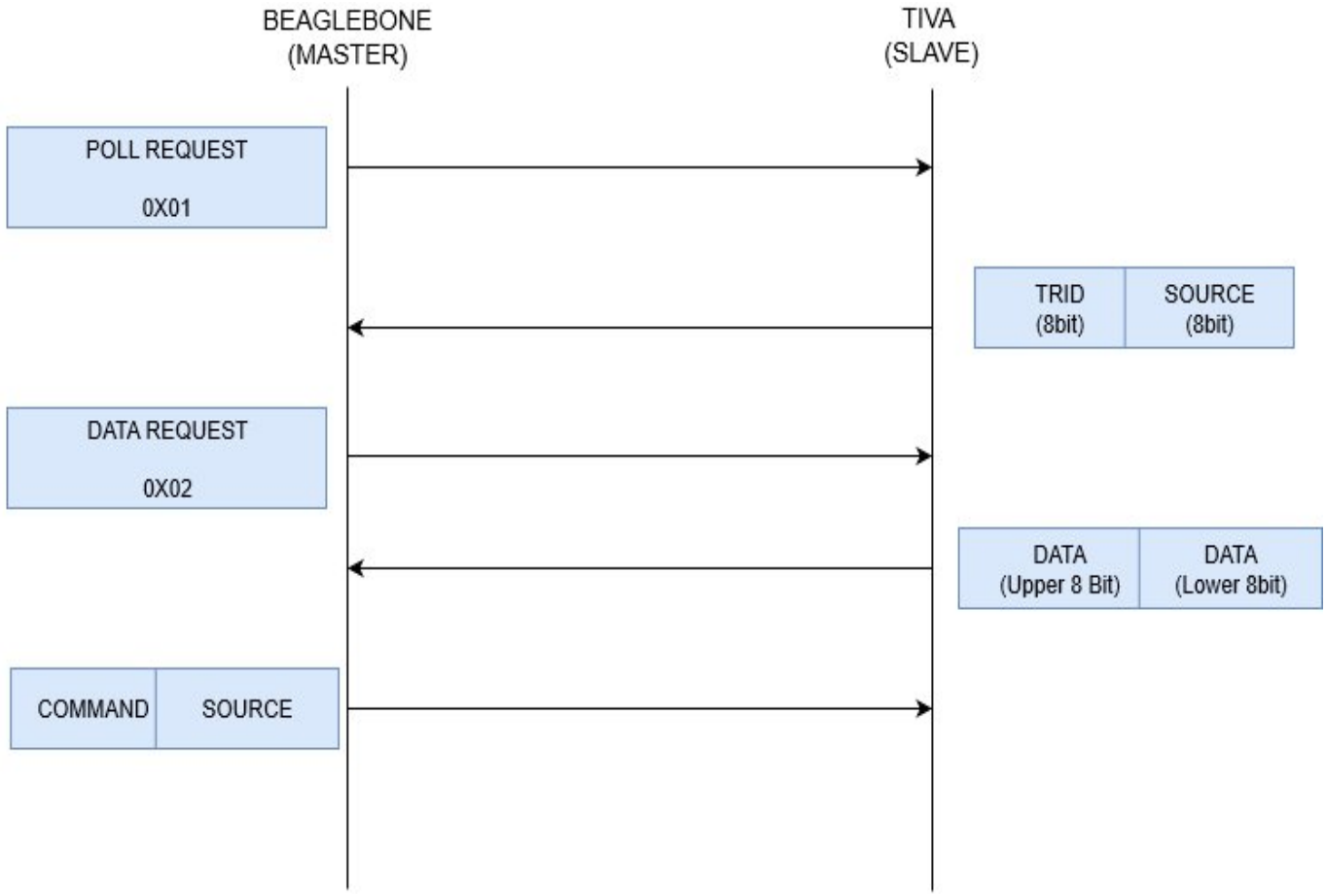
**INTERBOARD SPI COMMUNICATION.**

The major part of our project is enabling inter-board communication between Beagle Bone and TIVA using SPI communication protocol.

- ➔ Beagle Bone Black (Control Node) is configured as the master and TIVA (Remote Node ) is configured as slave
- ➔ The Beaglebone initiates communication by sending a poll command (0x01) to TIVA. TIVA receives this command and sends a 16 bit packet. The lower 8 bits of the packet represents source of the data and upper 8 bits represent the Transaction ID.
- ➔ BeagleBone receives this packet and parses the source and transaction id. If the transaction id is the same as the previous transaction id , this indicates that the data is old and should be discarded. In such a case , the master again sends a poll request (0x01 ) to the slave.
- ➔ If the transaction id is different than the previous one, this indicates the presence of valid data and so, the master sends a Get Data Command to the slave.
- ➔ The slave receives this command and sends valid sensor data to the master.
- ➔ After receiving valid sensor data, the master again sends the poll request and repeats the above steps.



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**KEY LEARNINGS**

**Puneet Bansal:**

- Learnt about SPI protocol and had a lot of practical exposure of the same. SPI was used for 2 aspects of the project. Firstly, to interface the SPI based temperature sensor with TIVA board and secondly to bring about inter-board communication. Enabling the SPI protocol on Beagle Bone was a bit challenging since it required a number of configurations.
- Making the inter-board SPI communication to work was the major learning curve. This involved deeply understanding what actually happens in SPI communication. While interfacing sensors, we are just concerned with master operations, the SPI sensor has its state machine to handle the transfer. However, in this the TIVA was enabled as slave and a state machine was developed to handle the transfer events.
- This project gave me understanding of how industry level projects should be. How everything is important starting from well thought project plan, development and final documentation. Apart from this handling error conditions like missing sensor, boards connected or not is something I learnt from this project/course and is something I would definitely implement in my other projects.
- Learnt about Free RTOS API's