

Master Project

Implementation and Performance Analysis of Precision Time Protocol on Linux based System-On-Chip Platform

Mudassar Ahmed
(Matr.Nr. 927837)

MSc. Information Engineering
Kiel University of Applied Sciences

May, 2018

1 Introduction

- Why Time Synchronization ?
- Available Solutions/Protocols
- Why this Project?

2 Methodology

- Tools and Technologies
- Establishing Test Environment
- Test Case scenarios
- Data Collections and Presentation

3 Results/Demo

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Introduction

Why Time Synchronization ?

- Time Critical Actions
- Distributed Computing.
- Some financial services require highly accurate timekeeping by law.
- Scheduled operations.
- Logging.
- Power system protection
- Control and automation
- Data communication applications utilizing an Ethernet communications architecture.

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- NTP.

Introduction

Available Solutions/Protocols

- NTP.
- GPS.

Introduction

Available Solutions/Protocols

- NTP.
- GPS.
- TTP and SERCOS:.

Introduction

Available Solutions/Protocols

- NTP.
- GPS.
- TTP and SERCOS:.
- Precision Time Protocol (PTP-1588).

Introduction

Available Solutions/Protocols

- NTP.
- GPS.
- TTP and SERCOS:.
- Precision Time Protocol (PTP-1588). *Self-Organizing ,
Sub-Microsecond level accuracy, *Hardware assisted (Optional).

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Why this Project?

- Enabling Hardware timestamping capabilities of BeagleBone Black
- Analyzing the behavior of PTP implementation, with simulated load.
- Analysis of precision uncertainty.
- Maximum attainable accuracy.

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- LinuxPTP (ptp4l, pmc and phy2sys).

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- stress-ng.

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- Matlab.

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- Matlab.
- Beaglebone Black (SoC Platform).

- LinuxPTP (ptp4l, pmc and phy2sys).
- stress-ng.
- iPerf.
- Matlab.
- Beaglebone Black (SoC Platform). Supports Hardware Assisted PTP Implementation.

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- Configuring a Linux kernel with PTP related options (CONFIG_PPS and PTP_1588_CLOCK).

- Configuring a Linux kernel with PTP related options (CONFIG_PPS and PTP_1588_CLOCK).
- Installing and Configuring necessary tools.
 - LinuxPTP
 - Stress-ng
 - iPerf
 - Matlab

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- Software Timestamping.

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- Hardware Timestamping.

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- Hardware Timestamping.
- Comparison of Software and Hardware based Synchronization.

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- Hardware Assisted Time Synchronization under I/O Load.
- Hardware Assisted Time Synchronization under Network Load.

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Methodology

Data Collection and Presentation(Test Sheet)

Test ID	PTP Demon Config			Stress Test Config		Load distribution	Remarks
	Message Frequency	Filter 1	Filter 2	Load type	Intensity		
HwT1.1	1						Slave: HW , Master: SW
HwT1.2	1						Slave: SW , Master: HW
HwT1.3	1						Slave: HW , Master: HW
HwT1.4	8						
HwT1.5	8						log data: phc2sys + ptpdl
HwT1.6	8						log data: phc2sys
HwT1.7	8						log data: phc2sys + ptpdl
HwT1.8	8			CPU	50	Slave Only	
HwT1.9	8			CPU	50	Both	
HwT1.10	8			CPU	100	Slave Only	
HwT1.11	8			CPU	100	Both	
HwT1.12	8			I/O	-	Slave Only	
HwT1.13	8			I/O	-	Both	
HwT1.14	8			CPU	100	Slave Only	log data: phc2sys + ptpdl
HwT1.15	8			CPU	100	Both	log data: phc2sys + ptpdl
HwT1.16	8			I/O	-	Slave Only	log data: phc2sys + ptpdl
HwT1.17	8			I/O	-	Both	log data: phc2sys + ptpdl
HwT1.18	8			Network	1Mb	Source: Alien	
HwT1.19	8			Network	5Mb	Source: Alien	
HwT1.20	8			Network	10Mb	Source: Alien	
HwT1.21	8			Network	20Mb	Source: Alien	
HwT1.22	8			Network	50Mb	Source: Alien	

Methodology

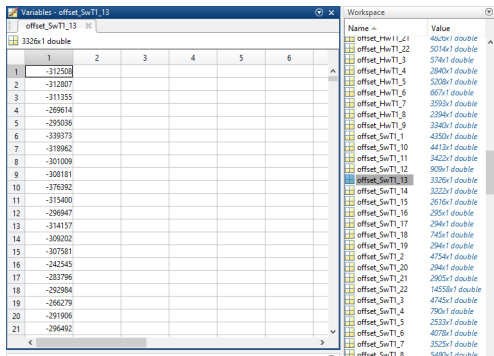
Data Collection and Presentation (Log File)

C:\Users\Mudassar\Desktop\master Project\PTPDATA\New Data\Sw\SwT1.13\SwT1.13.txt - Notepad+

Line	Date/Time	Device	Protocol	Source IP	Status	Destination IP	Freq	Path	Delay
1	Dec 17 14:48:34	my-new-beaglebone-2	ptp41:	[569.999]	master offset	-312508	0 freq	+33516 path	delay 106651
2	Dec 17 14:48:34	my-new-beaglebone-2	ptp41:	[570.115]	master offset	-312807	0 freq	+33516 path	delay 106651
3	Dec 17 14:48:34	my-new-beaglebone-2	ptp41:	[570.240]	master offset	-311355	0 freq	+33516 path	delay 106651
4	Dec 17 14:48:35	my-new-beaglebone-2	ptp41:	[570.365]	master offset	-296614	0 freq	+33516 path	delay 106651
5	Dec 17 14:48:35	my-new-beaglebone-2	ptp41:	[570.490]	master offset	-295036	0 freq	+33516 path	delay 106651
6	Dec 17 14:48:35	my-new-beaglebone-2	ptp41:	[570.615]	master offset	-339373	0 freq	+33516 path	delay 106651
7	Dec 17 14:48:35	my-new-beaglebone-2	ptp41:	[570.740]	master offset	-318962	0 freq	+33516 path	delay 106651
8	Dec 17 14:48:35	my-new-beaglebone-2	ptp41:	[570.865]	master offset	-301009	0 freq	+33516 path	delay 106651
9	Dec 17 14:48:35	my-new-beaglebone-2	ptp41:	[570.991]	master offset	-308191	0 freq	+33516 path	delay 106651
10	Dec 17 14:48:35	my-new-beaglebone-2	ptp41:	[571.115]	master offset	-376392	0 freq	+33516 path	delay 107566
11	Dec 17 14:48:35	my-new-beaglebone-2	ptp41:	[571.241]	master offset	-315400	0 freq	+33516 path	delay 107566
12	Dec 17 14:48:36	my-new-beaglebone-2	ptp41:	[571.366]	master offset	-296947	0 freq	+33516 path	delay 107566
13	Dec 17 14:48:36	my-new-beaglebone-2	ptp41:	[571.491]	master offset	-314157	0 freq	+33516 path	delay 108482
14	Dec 17 14:48:36	my-new-beaglebone-2	ptp41:	[571.616]	master offset	-309202	0 freq	+33516 path	delay 108482
15	Dec 17 14:48:36	my-new-beaglebone-2	ptp41:	[571.741]	master offset	-307581	0 freq	+33516 path	delay 108482
16	Dec 17 14:48:36	my-new-beaglebone-2	ptp41:	[571.867]	master offset	-242545	0 freq	+33516 path	delay 108482
17	Dec 17 14:48:36	my-new-beaglebone-2	ptp41:	[571.992]	master offset	-283796	0 freq	+33516 path	delay 108482
18	Dec 17 14:48:36	my-new-beaglebone-2	ptp41:	[572.117]	master offset	-292994	0 freq	+33516 path	delay 108752
19	Dec 17 14:48:36	my-new-beaglebone-2	ptp41:	[572.242]	master offset	-266279	0 freq	+33516 path	delay 108752
20	Dec 17 14:48:37	my-new-beaglebone-2	ptp41:	[572.367]	master offset	-291906	0 freq	+33516 path	delay 108752
21	Dec 17 14:48:37	my-new-beaglebone-2	ptp41:	[572.493]	master offset	-296452	0 freq	+33516 path	delay 108752
22	Dec 17 14:48:37	my-new-beaglebone-2	ptp41:	[572.618]	master offset	-301785	0 freq	+33516 path	delay 108752
23	Dec 17 14:48:37	my-new-beaglebone-2	ptp41:	[572.743]	master offset	-258412	0 freq	+33516 path	delay 108752
24	Dec 17 14:48:37	my-new-beaglebone-2	ptp41:	[572.868]	master offset	-237081	0 freq	+33516 path	delay 108752
25	Dec 17 14:48:37	my-new-beaglebone-2	ptp41:	[572.993]	master offset	-293413	0 freq	+33516 path	delay 108752
26	Dec 17 14:48:37	my-new-beaglebone-2	ptp41:	[573.118]	master offset	-278082	0 freq	+33516 path	delay 108752
27	Dec 17 14:48:37	my-new-beaglebone-2	ptp41:	[573.243]	master offset	-282957	0 freq	+33516 path	delay 108752
28	Dec 17 14:48:38	my-new-beaglebone-2	ptp41:	[573.369]	master offset	-273251	0 freq	+33516 path	delay 108752
29	Dec 17 14:48:38	my-new-beaglebone-2	ptp41:	[573.494]	master offset	-280333	0 freq	+33516 path	delay 108752
30	Dec 17 14:48:38	my-new-beaglebone-2	ptp41:	[573.619]	master offset	-274580	0 freq	+33516 path	delay 108752
31	Dec 17 14:48:38	my-new-beaglebone-2	ptp41:	[573.744]	master offset	-267791	0 freq	+33516 path	delay 108752
32	Dec 17 14:48:38	my-new-beaglebone-2	ptp41:	[573.869]	master offset	-263104	0 freq	+33516 path	delay 108482
33	Dec 17 14:48:38	my-new-beaglebone-2	ptp41:	[573.994]	master offset	-270561	0 freq	+33516 path	delay 108482
34	Dec 17 14:48:38	my-new-beaglebone-2	ptp41:	[574.119]	master offset	-274935	0 freq	+33516 path	delay 108482
35	Dec 17 14:48:38	my-new-beaglebone-2	ptp41:	[574.245]	master offset	-273310	0 freq	+33516 path	delay 108482
36	Dec 17 14:48:39	my-new-beaglebone-2	ptp41:	[574.370]	master offset	-254351	0 freq	+33516 path	delay 108482
37	Dec 17 14:48:39	my-new-beaglebone-2	ptp41:	[574.495]	master offset	-267473	0 freq	+33516 path	delay 108482
38	Dec 17 14:48:39	my-new-beaglebone-2	ptp41:	[574.620]	master offset	-198432	0 freq	+33516 path	delay 108482
39	Dec 17 14:48:39	my-new-beaglebone-2	ptp41:	[574.745]	master offset	-212345	0 freq	+33516 path	delay 108482
40	Dec 17 14:48:39	my-new-beaglebone-2	ptp41:	[574.870]	master offset	-262800	0 freq	+33516 path	delay 108482
41	Dec 17 14:48:39	my-new-beaglebone-2	ptp41:	[574.995]	master offset	-254755	0 freq	+33516 path	delay 108482
42	Dec 17 14:48:39	my-new-beaglebone-2	ptp41:	[575.120]	master offset	-239961	0 freq	+33516 path	delay 108482
43	Dec 17 14:48:39	my-new-beaglebone-2	ptp41:	[575.246]	master offset	-248094	0 freq	+33516 path	delay 108482
44	Dec 17 14:48:40	my-new-beaglebone-2	ptp41:	[575.371]	master offset	-249748	0 freq	+33516 path	delay 108482
45	Dec 17 14:48:40	my-new-beaglebone-2	ptp41:	[575.496]	master offset	-211119	0 freq	+33516 path	delay 108482
46	Dec 17 14:48:40	my-new-beaglebone-2	ptp41:	[575.621]	master offset	-257112	0 freq	+33516 path	delay 109022

Methodology

Data Collection and Presentation (Matlab Workspace)



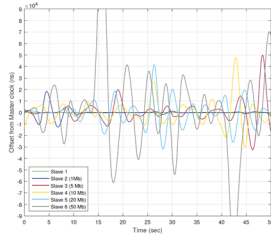
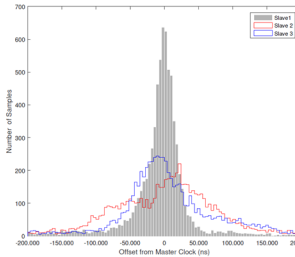
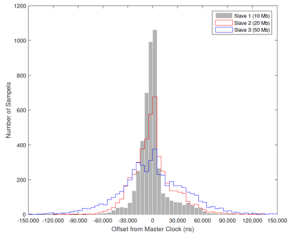
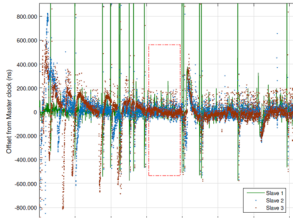
The screenshot displays the MATLAB workspace with two windows. The left window, titled 'Variables - offset_SwT1_13', shows a table with 21 rows and 6 columns. The first column is labeled '1' and contains numerical values. The second column is labeled '2' and is empty. The other columns are labeled '3', '4', '5', and '6' and are also empty. The right window, titled 'Workspace', shows a list of variables with their names and values. The variable 'offset_SwT1_13' is highlighted in blue.

	1	2	3	4	5	6
1	-312508					
2	-312807					
3	-311355					
4	-269614					
5	-295036					
6	-339373					
7	-318962					
8	-301009					
9	-308181					
10	-376392					
11	-315400					
12	-296947					
13	-314157					
14	-309202					
15	-307581					
16	-242545					
17	-283796					
18	-292984					
19	-266279					
20	-291906					
21	-296492					

Name	Value
offset_HwT1_1	4820r1 double
offset_HwT1_22	5014r1 double
offset_HwT1_3	574r1 double
offset_HwT1_4	2840r1 double
offset_HwT1_5	5208r1 double
offset_HwT1_6	667r1 double
offset_HwT1_7	3593r1 double
offset_HwT1_8	2394r1 double
offset_HwT1_9	3340r1 double
offset_SwT1_1	4350r1 double
offset_SwT1_10	4413r1 double
offset_SwT1_11	3422r1 double
offset_SwT1_12	920r1 double
offset_SwT1_13	3326r1 double
offset_SwT1_14	3222r1 double
offset_SwT1_15	2616r1 double
offset_SwT1_16	295r1 double
offset_SwT1_17	294r1 double
offset_SwT1_18	745r1 double
offset_SwT1_19	294r1 double
offset_SwT1_20	4754r1 double
offset_SwT1_21	294r1 double
offset_SwT1_22	2905r1 double
offset_SwT1_3	14558r1 double
offset_SwT1_4	4745r1 double
offset_SwT1_5	790r1 double
offset_SwT1_6	2533r1 double
offset_SwT1_7	4078r1 double
offset_SwT1_8	3525r1 double
offset_SwT1_9	5480r1 double

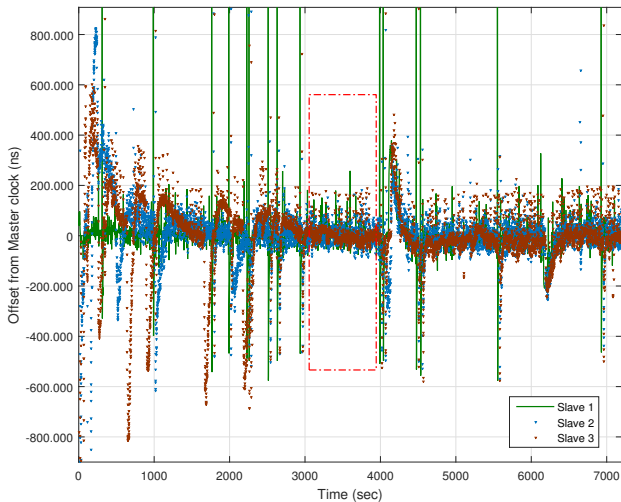
Methodology

Data Collection and Presentation (Data Presentation)



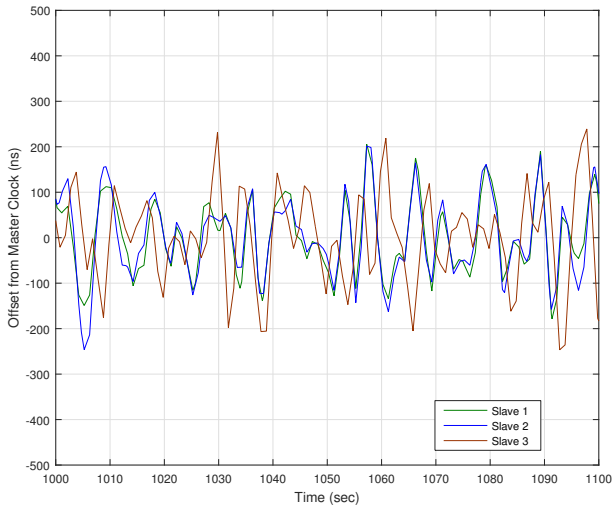
Results/Demo

Software Timestamping based Time Synchronization



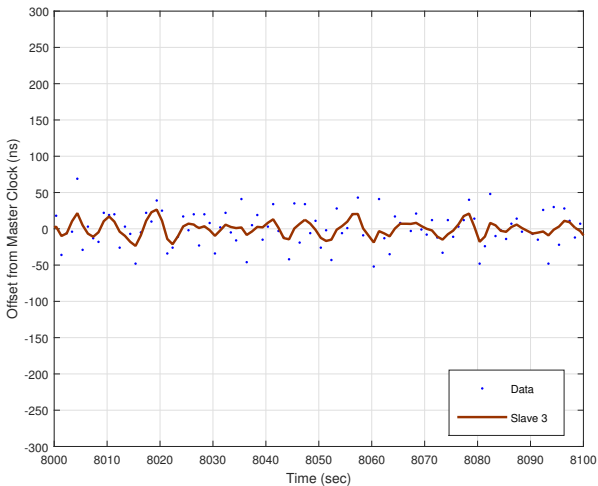
Results/Demo

Hardware Timestamping based Time Synchronization (Multiple Slaves)



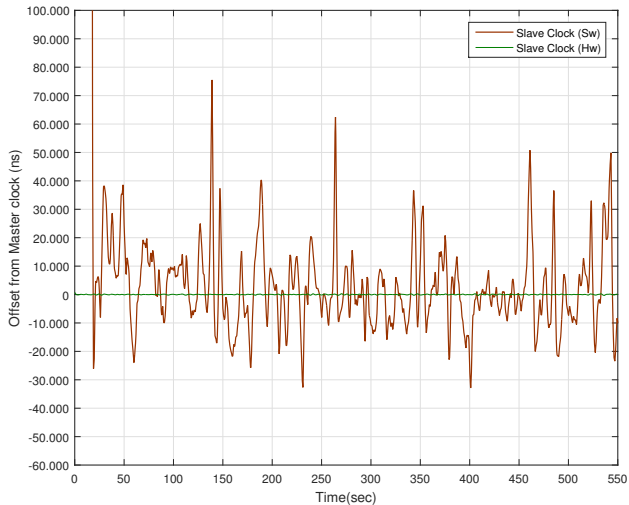
Results/Demo

Hardware Timestamping based Time Synchronization (Single Slave)



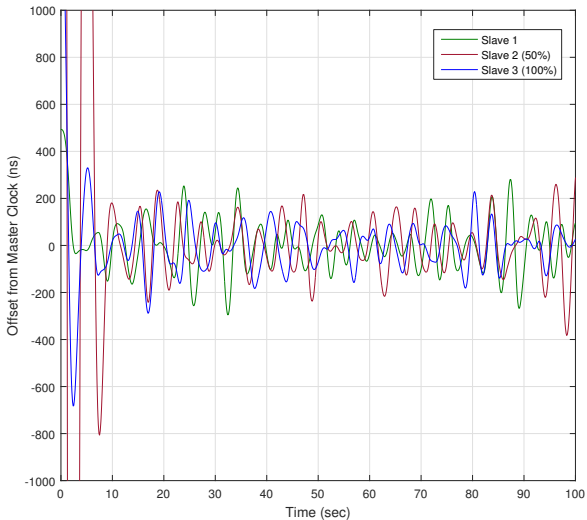
Results/Demo

Comparison of Hardware and Software based Time Synchronization



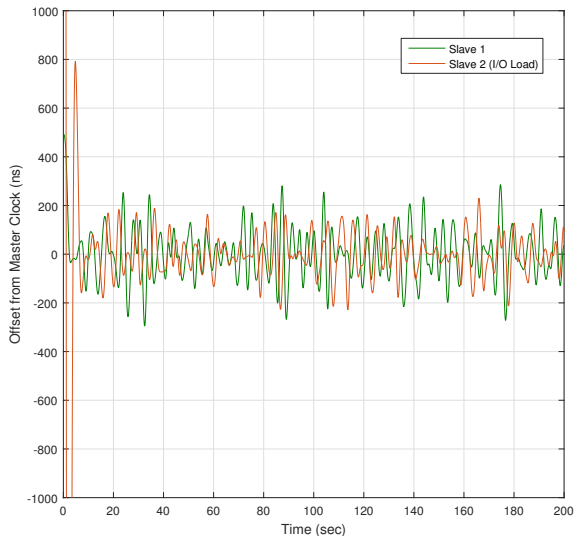
Results/Demo

Hardware Assisted Time Synchronization under CPU Load



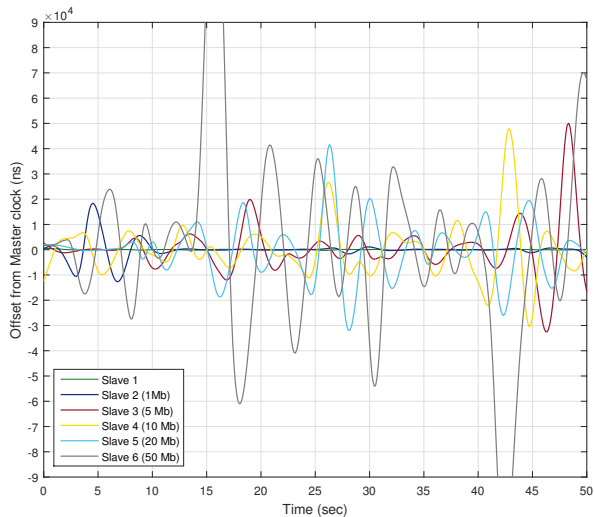
Results/Demo

Hardware Assisted Time Synchronization under I/O Load






Results/Demo

Hardware Assisted Time Synchronization under Network Load



- In Software only solutions, the average offset of slave clocks remained between $\pm 0.5\text{ms}$
- In Hardware based implementations, the accuracy of $\pm 200\text{ns}$ was frequently achieved.
- In load case scenarios, apparently network traffic based tests showed some considerable effects.

-  IEEE Std 1588 -2008 (Revision of IEEE Std 1588-2002) .
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-  Kendall Correll, Nick Barendt and Michael Branicky .
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