Expertise
and insight
for the future

Trinh Doan

# Precise Positioning Concept and NTRIP Base Station

Metropolia University of Applied Sciences

Bachelor of Engineering

Electronics Engineering

Bachelor's Thesis

Date: 4 December 2019



Metropolia
University of Applied Sciences

| | |
|---|---|
| Author(s)<br>Title<br><br>Number of Pages<br>Date | Trinh Doan<br>Precise Positioning Concept and NTRIP Base Station<br><br>43 pages + 2 appendices<br>4 December 2019 |
| Degree | Bachelor of Engineering |
| Degree Programme | Electronics |
| Specialisation option | Name of the specialisation option |
| Instructor(s) | Miika Ihonen, Manager at Kindhelm company<br>Heikki Valmu, Senior Principal Lecturer at Metropolia UAS |

The purpose of this project is to discuss basic idea of precise satellite positioning. When it comes to positioning area, GPS has been acknowledged to be the most popular concept. However, positioning signal is not simple as that. With this in mind, GNSS is actually the ultimate definition of positioning satellite. Global Navigation Satellite System (GNSS) refers to all constellations of satellite providing positioning signal from the space down to the Earth. Besides GPS developed by USA, GNSS includes Russia's GLONASS, Europe's Galileo and China's Beidou Navigation Satellite System. Moreover, there are less utilized constellations such as Japanese QZSS, Indian IRNSS, etc.

Mostly, GNSS signal has been utilized together with different types of protocol in order to increase precision of receivers. The two protocols are introduced in this paper is Precise Point Positioning and Real-time Kinetic (RTK). However, the more popular protocol RTK is analyzed more into details and an instruction has been given in order to build an RTK base station. RTK system helps receivers reach to precision of 1-3 centimeters offset. RTK system is extremely useful in autonomous off-road vehicle.

| | |
|---|---|
| Keywords | GNSS, GPS, RTK, RTCM, NTRIP, base station. |

**Table of Contents**


1 Introduction 1
1.1 GNSS Market Size 1
1.2 Satellite Positioning Fundamental Working Principle 3

2 Project Background 5

3 Precise Positioning Concept 6

3.1 Range Measurement 6
3.1.1 Carrier Phase Ranging 7
3.1.2 PRN (Pseudo-Random Noise) 7
3.2 Precise Point Positioning System 9
3.3 Classical Differential GNSS (DGPS) 9
3.4 RTK Positioning Technique 11
3.5 RTCM Protocol and NTRIP System 11

4 Elements of NTRIP Base Station 13

4.1 Necessary Software (BKG Ntripserver) 13
4.2 Review of Components 15
4.2.1 Tracking Satellite Device (U-Blox ZED-F9P) 15
4.2.2 Microprocessor-Beaglebone Black (BBB) 20
4.2.3 Internet Module (Quectel EvB Board and Quectel EG25-G) 24

5 Construction of Ntrip Base Station 26

5.1 ZED-F9P 26
5.2 Beaglebone Black and ZED-F9P Connection 31
5.3 BKG Ntripserver on Beaglebone Black 34
5.4 Quectel EG25-G Configuration 37

6 Future Development and Conclusion 39

Reference 41

**Appendices**

Appendix 1 Set up UART Pins on Beaglebone Black

Appendix 2 Run Ntripserver Automatically

## List of Abbreviations

| | |
|---|---|
| BBB | Beaglebone Black |
| BKG | Bundesamt für Kartographie und Geodäsie |
| DGNSS | Differential GNSS |
| GNSS | Global Navigation Satellite System |
| NTRIP | Networked Transport of RTCM via Internet Protocol |
| PPP | Precise Point Positioning |
| PRN | Pseudo-Random Noise |
| RTCM | Radio Technical Commission for Maritime |
| RTK | Real-time kinematic |

# 1 Introduction

As human technology has been developing over decades, satellite is always one of the most essential aspects. Firstly, the exact definition of satellite based on NASA explanation is a planet or a machine that orbits around a certain planet [1]. However, a “satellite” is usually acknowledged to be an artificial machine that is launched from the Earth to space. Satellites play a crucial role in our society nowadays. They can be used for different purposes such as weather forecast, telecommunication, etc. Despite that, in this paper, “satellite” is mentioned with the purpose of positioning only.

The term Global Navigation Satellite System (GNSS) refers to all satellites providing signals from space down to the Earth. These signals may be positioning data, or timing, velocity data or all of them. That is to say, there are two main elements in order to build GNSS, downstream and upstream system. Upstream system consists of those factors relating to build space infrastructure (satellites). In addition, upstream system has to deal with the issue of streaming data down to receivers on the Earth. While downstream system’s responsibility is to receive the signal from upstream system. Moreover, it also includes the tasks of providing relating services and products to customer. Regarding to this paper, downstream industry is a more well-discussed topic.

## 1.1 GNSS Market Size

Europe Global Navigation Satellite Systems Agency (Europe GSA), an organization studying the economic development of GNSS services and technology, has published a statistic on October 15, 2019, proving that GSS is a global billion-dollar industry. Besides, they also predict its global revenue growth in the next few years. According to the calculation, the total economic size of GNSS services in 2029 is approximately twice as what it was in 2019. [2.]

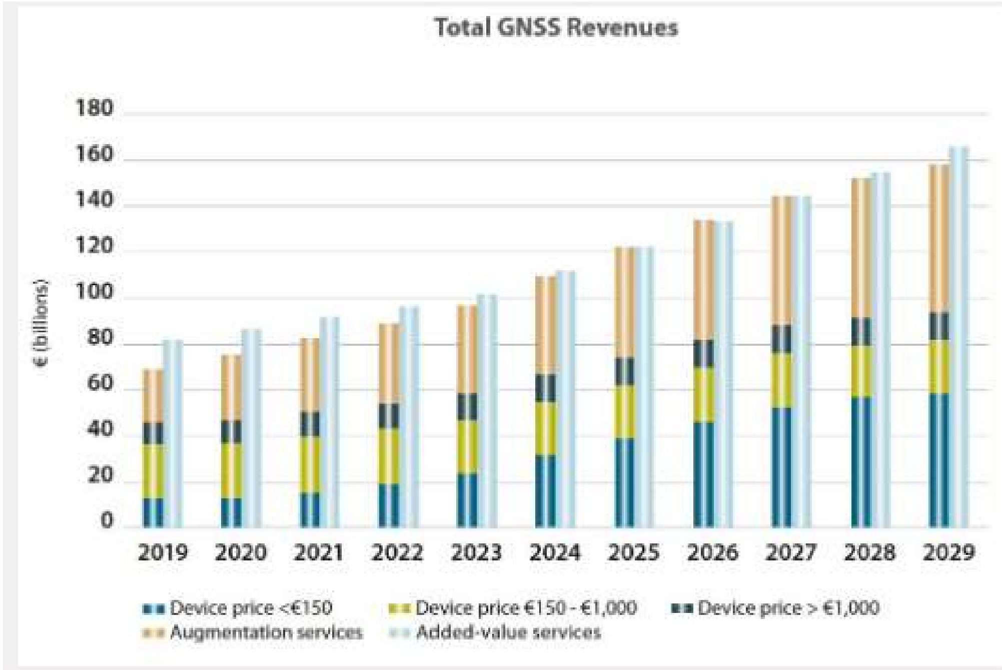



Figure 1: Market Size of Downstream Satellite System over years-Europe GSA's Analysis [1]

More relating to the analysis, the annual growth of the GNSS market (augmentation services revenue) that can be seen from the graph in figure 1 is roughly 4%. The term augmentation is a concept describing a method that increases accuracy of GNSS signal, which also grows steadily over years. In the meantime, the same element of the added-value services, a well-known term in industry for all services beyond the standardization, has the biggest market size. [2.]

Studying more into details, Europe GSA has analyzed the contribution of different GNSS segments to its own cumulative revenue from 2019-2029.


Figure 2: Europe GSA’s analysis of contribution of each GNSS segment [1]

As it is shown in figure 2, it is not surprised that applications in Customer Solutions and Road area have the most influence on the overall market with being in possession of 38.3% and 55% respectively. These applications are widely and daily used by users all around the world. It means that other aspects, including Agriculture, Maritime, Surveying, etc. contribute only 6.7%. [2.]

In conclusion, Downstream Satellite system has an enormous distribution to the World’s Economy. And Positioning Satellite dominates the total contribution of different Satellite segments.

## 1.2 Satellite Positioning Fundamental Working Principle.

One of the most foremost question when we encounter a technology is about its science rule behind those fascinating components that has been built into a whole system. It may fascinate many people when they find out that satellite positioning system, one of the most intelligent technology human being has ever achieved, is built on one of the most fundamental geometry equation, which is distance equals time multiplied by velocity [3]. If time and speed of signal are known, distance from satellites and receiver can be withdrawn from the equation. Another key thing to emphasize is that receiver usually does not receives signal from one single satellite. Indeed, it interacts with multiple satellites at the same time.  Based on that, satellites can define the approximate location of the receiver. The following figure 3 demonstrates the idea.

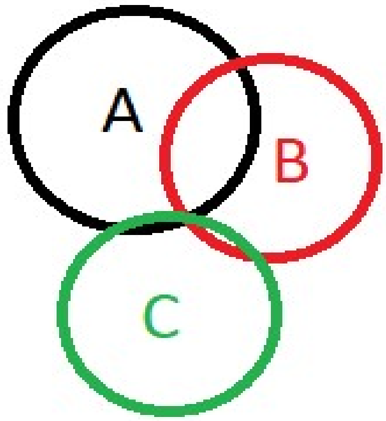



Figure 3: Illustration of how satellites locate receiver

. For examples, a receiver on the Earth is getting positioning signal from three satellites A, B, C. Three circles A, B, C represent for possible positions of the receiver to the three satellites respectively. The intercross among those circles would define where the receiver is on the Earth.

The first issue scientists need to solve before building a positioning satellite system is that how they can define “time” element in space. Thanks to the invention of atomic clock, “time” is not a frustrating obstacle [3]. Atomic clocks are the most accurate clocks that have been invented, which helps to deliver a more accurate signal from space down to the Earth. The procedure of sending and receiving signal from space to Earth is as follow: Satellite will send a radio wave signal to receiver. As soon as receiver gets it, it will send back another radio wave. The function of atomic clock is to measure how long it takes when satellite starts to send data until it gets another radio wave from receiver. That is how scientist define “time” in satellite system. In addition, the speed of radio wave is the speed of light which is 300.000 km/h. When “Time” and “Velocity” are known, “distance” can be calculated.

Despite that, there is one flaw in this technique. The clock connected to receiver on the Earth may not be perfectly synchronized to the atomic clock out of space, which leads to poor accuracy of several meters, not to mention to noise effect and power loss during transmission. The solutions for these obstacles will be discussed in Chapter 3.

Overall, by measuring the distance between satellites and receiver, satellites can locate where receiver currently is. One key thing to remember is that accuracy of the measurement can be varying depending on technology and technique being used. For example, GPS activated on smartphone provides locations with the accuracy within 4.9 m most of the time [3]. However, nowadays there are many solutions to provide a better positioning signal. One of those is called NTRIP technique. A NTRIP system consists of three main sections: NTRIP client, NTRIP caster and NTRIP server. NTRIP Base Station- sometimes called RTK Base Station- contains NTRIP server to transmit data over Internet. This paper explains the general idea of Precise Positioning as well as NTRIP system and propose how to construct a NTRIP base station

## 2 Project Background

Nowadays, autonomous vehicle is an intriguing aspect that many famous car brands such as Tesla or Audi, focus on developing. However, that is the concept of on-road vehicle which is not discussed in this paper. Of course, they do not merely use GNSS satellite signal to create those self-driving cars. It is quite obvious that on-road vehicles have to interact with other moving ones like them. Even though GNSS technology is extremely advanced with the accuracy of a few centimeters, it is still risky to rely on GNSS signals. Because having crowded moving objects in a same space, accidents will occur with nothing more than a few mistaken millimeters. In contrast to on-road automobile, tractor using in agriculture is a suitable object. To put it in another way, it is feasible to make use of GNSS signal in order to create a self-operating tractor.

The first self-driving tractor was invented by Frank W. Andrew around the early of 1940 [4]. It is understandable that this was a low-tech tractor. Frank W. Andrew controlled the tractor's steering wheel by the power of wind. Over decades, many big companies in the field of vehicle in general and specifically in agriculture, have tried to build their own autonomous tractors but nothing remarkable stands out. It was not until 2011 that the idea of self-operating tractors emerged significantly again. Ever since, it has become a new beneficial product to be invested.

An autonomous tractor is built to work without the manual handling from human like other self-driving vehicles. That is why it should be able to define its location itself as well as self-steer its path. This is where GNSS technology becomes useful. Some additional features are required, such as self-calculating and deciding its speed, self-avoiding obstacles like animals or trees. However, customers still have control over their tractors. It is an essential job for manufacturers to develop an application that helps their customers to have reign over their own tractors. Usually, these apps can be applied in a tablab or PC, which is genuinely convenient. Overall, driverless tractors combine different technologies together. Among those technologies, GNSS system still plays an irreversible part.

Kindhelm is one of the companies that paves their way to achieve such goals. Kindhelm is a company that offers precise positioning solution for unmanned vehicle in Finland. Their main targeting field recently is agriculture. As the industry requires, Kindhelm provides systems that afford high precise signal. In addition, the company also wants to reduce manual handling and human interference, that is why every product of them has to meet the requirements of continuous operation before being released to the market. Another must-have feature of unmanned vehicles is that they should be operating without any surprised or sudden error. Likewise, Kindhelm ensures the reliability of their products.

One of the techniques being studied by the company is NTRIP. Even though this technique is still under RnD process, this is a very promising idea that can make a breakthrough to the company in the future. As RTK base station is one of the projects of Kindhelm, this paper is published with the agreement of the company.

# 3 Precise Positioning Concept

## 3.1 Range Measurement

Nowadays, there are considerable means in order to achieve centimeters precision in positioning with different technologies and topologies, for example: DGPS, RTK, PPP, etc. However, one shared-key characteristic among those methods is that they all fix the downlink signals so that their ultimate accuracy is optimized. Clearly, the main problem in transmitting positioning signal, as mentioned in chapter 1, is the non-synchronization between two clocks on the Earth and out of space. However, focusing on synchronizing those clocks is not an easy task. Instead, researchers have come up with variety of different techniques in transmitting signal and determining "travelling time" of it as a substitute of the classical method.

#### 3.1.1 Carrier Phase Ranging

Carrier Phase Ranging is one of the most widely used methods of measurement in order to get precise GNSS signal and it is the keystone of PPP and RTK.

GNSS satellites send out signals with two main frequencies which are L1 at 1575.45 MHz and L2 at 1227.6 MHz. In addition, downlink signals are radio signals, which means they are at speed of light being equal to 300 000 000 m/s. The topology in Carrier Phase Ranging is that receivers would be able to analyse how many periods it gets for GNSS signals to be transmitted from the satellites to them [5]. When "periods" are known, "travelling time" can be withdrawn by using the following equation:

$$t = \frac{n}{f} \tag{1}$$

Where "n" is a real number indicating the number of "periods". The reason why "n" is a real number is that when signal gets to receivers, there are chances that it has not finished its current period.

In conclusion, Carrier Phase Ranging is an extremely high precise measurement of distance between satellites and receivers. Its error in measuring can be limited to 2 mm [5]. However, in order to achieve such a goal, receivers must be built with special equipment which can solve input carrier signal up to its fractional phase. Nowadays, not many receivers are able to manage to do that. The general accuracy of Carrier Phase Raging is around 3 cm [6].

#### 3.1.2 PRN (Pseudo-Random Noise)

PRN is a noise signal generated on purpose in order to define the identification of satellites, measuring satellite-to-receiver distance [6]. PRN code is not entirely random. It is created based on a specific rule or pattern, which is why it is called "Pseudo". There are two main types of PRN code: C/A code and P code. The C/A code contains series of chips. Chip is the same as bit except for chip does not contain any information. C/A code uses L1 carrier frequency. After 1203 chips, it repeats itself. C/A code rate is 1.023 Mbps, which mean there are 1203 chips transmitted every 1 ms. Furthermore, the total length of 1203-chip message is 299.8 km, and the distance between each chip equals to 293m [7]. C/A code is a basic PRN code and is applied widely in people's daily need.

There is another kind of PRN code which is more advanced. P code or Precise code has utilized both l1 and l2 carrier frequencies at 10.23 Mbps. The whole length of a sequence of P-code is $6.187104 * 10^{12}$ chips and the cycle repeat itself every 7 days [7], which scales down the uncertainty of accuracy. This method is mainly used in military purposes.

Every satellite has its own specific PRN code. Therefore, when receivers pick up a signal, they would know which satellite it comes from. This idea is reasonably straightforward enough to understand immediately. However, the interesting feature of PRN is how it is governed to measure the distance between satellite and receiver. In this system, receiver locally generates a replica of PRN corresponding to the signal it receives. After receiving a PRN code from a specific satellite, receiver would shift its local PRN to the original one until those code matched. Knowing how far it has to shift the local code, receiver would be able to define the required distance. This is an academic explanation, which is quite incomprehensible. In order to understand the theory of using PRN code to measure distance from space to Earth, visualise that PRN code generated local inside receiver is a measuring tape. This virtual tape is so long that it is able to measure the length of invisible signal coming in by syncing up the replica PRN inside receiver and original PRN sent from satellite. Synchronizing the two codes ensures that receiver is measuring distance from the right satellite. In addition, it is the key that helps receiver knows how to scale the incoming code.

The reason why sinusoidal signal is not used instead of Pseudo-random noise in terms of measuring distance is that sinusoidal wavelength is identical in each period, which will easily cause false synchronization. False synchronization means that two signals seem to be synchronized but they are out of phase. PRN can reduce significantly possibility of such a problem.

## 3.2 Precise Point Positioning System

PPP is one of the most common precise solutions. Precise Point Positioning is a single receiver system, unlike from RTK mentioned later in this paper which uses another nearby receiver as a virtual base station. There are two main elements of PPP: observables and ephemeris [8]. In PPP system, receivers are able to detect dual L1/L2 frequencies and utilize both PRN and Carrier-Phase code. This feature is called “observables” because those signals can pick up directly from the space.

The second element is ephemeris. Ephemeris is a crucial element in Precise Positioning generally and PPP specifically. General definition of ephemeris is a parameter presenting trajectory (moving path) of satellites or astronomical objects [9]. In High Precise Positioning concept, ephemeris is usually understood in a further way. It refers to precise measurement of GNSS signal processed by International GNSS Service (IGS) and some other relating organizations. The main function of ephemeris in positioning is to provide position of satellites at the current moment and in a near future as precisely as possible 10]. Besides orbit of satellite, clock data correction is also a crucial task [10], which forms the second element of PPP, ephemeris.

To put it in a nutshell, PPP makes use of both GNSS signal frequencies and applies ephemeris so that receivers know the precise location of satellites and their clock state. The main disadvantage of PPP is that it takes a long time for PPP receivers get into fixed mode. The general time at setup of PP receivers before getting fixed is around 20-40 minutes.

## 3.3 Classical Differential GNSS (DGPS)

Classical Differential GNSS or DGPS is the advanced version of GPS which provides receiver its precise location by using another fixed and high-precise receiver called reference station.

In order to achieve a reference station, this method solves the errors caused by the following factors during signal transmission: ephemeris prediction, satellite clock, environmental delay (ionospheric and tropospheric). DGNSS algorithm stands out as a demonstration of the range between satellite and receiver without using any correction method [11]

$$P = p + I + Tr + c(b_{Rx} - b_{Sat}) + \varepsilon_p \quad (2)$$

Where:

I: delay caused by ionosphere

Tr: delay caused by troposphere

b(Rx): Clock offset at receiver corresponding to GPS time (A standard reference clock)

b(Sat): Clock offset at satellite corresponding to GPS time

c: speed of light

$\varepsilon_p$: noise in measurement component

The key thing to remember in this algorithm is P is a vector. Therefore, the vector of distance between reference station to receiver can be withdrawn from the differential between P from satellite to reference station and P from satellite to receiver. The beauty of this differential is that it would eliminate all the errors such as delay in atmosphere, clock offset, to each other because two receivers endure the similar effects from environment. Based on that differential, the precise distance and location of receiver from reference station should be known. As the reference station is, indeed, a precise receiver, the user location should be precisely defined.

In order to get a high precise reference station, another receiver is studied in surveyed mode, which averages its location over time until it gets to a fixed location. This process usually takes 12-18 hours [12]. In addition, DGPS uses PRN ranging measurement for calculating its location [12], which is main difference from its similar method RTK discussed in next chapter.

Overall, by setting a reference station at a precisely defined location, DGPS method can determine where receiver is in a high precise way. The accuracy of DGPS is ambiguous from 3 cm to almost 1 meter depending on each system [12]. One fascinating feature of DGPS comparing to PPP is that user can get into fixed much faster.

### 3.4 RTK Positioning Technique

RTK is another positioning technique which is similar to DGPS using a second receiver as a base station. Usually, in RTK system, the receivers of users are called rovers. As discussed before, RTK use carrier-phase range measurement which results in higher precision. Otherwise, every characteristic of RTK is almost the same as DGPS. However, RTK has two modes of base station: stationary and moving base. Stationary base is nothing much different from DGPS method except for its ranging measurement. In addition, its working distance is around 10-20 kilometres. [13.] According to each specific project, engineers have to calculate how many base stations needed and where to locate those stations so that rovers always have clear access to at least one base station.

In moving base station system, both rover and base can move at the same time. In this case, correction signals transmitted from base have to be in the same sample rate as receiving rate at rover. This method is spectacularly useful when it needs to solve the tilting of vehicles.

In general, RTK is a technique that has a better accuracy than DGPS. Also, it allows base station moving along to rover in some application.

### 3.5 RTCM protocol and NTRIP system

Radio Technical Commission for Maritime Services (RTCM) is non-profit organization which develops and provides international maritime standards for radio navigation and communication. It was initially started in 1947 by U.S government. Over several developing decades, it has gradually become an independent organization. Its members nowadays spread all over the world including both government and non-government participants. Every year, there is a conference held by RTCM at a specific place in order to discuss and update new standards concerning to maritime system. In area of precise differential positioning, RTCM also invents many useful standards and protocols, which is referred as "RTCM corrections". RTCM correction is currently the most applicable standard applied in RTK system [14.].

The newest version is RTCM 3.3 which is supplemented with more Position and Communication standard messages. These messages cover most of the aspects relating to any differential positioning system.

RTCM is an ideal standard and protocol in terms of correcting satellite signals, which contributes to RTK systems as a method of achieving precise location. However, the system still needs another protocol in order to establish a mutual communication link between its base station and rover. This is where the so-called NTRIP stands out. In other words, RTCM and NTRIP protocols materialize the concept of an RTK system. Furthermore, because NTRIP has been the only transmitting protocol applied to RTK, NTRIP and RTK sometimes might be understood as the same definition. NTRIP (Networked Transport of RTCM via Internet Protocol) is another protocol used in RTK system to transmit differential correction data as RTCM standard over Internet. It was first introduced by the Federal Agency for Cartography and Geodesy of Germany (B.K.G) in late 2004. There are three major parts of a NTRIP system: Caster, Client and Server [15].

Firstly, Caster plays a role as a HTTP server which generate a mutual place for its client to communicate to each other [15]. In this case, HTTP client is NTRIP Client and NTRIP Server. Caster usually runs in a separate PC all the time. SNIP is one of the most conventional NTRIP casters nowadays. NTRIP caster would allow users to create at least a mountpoint name and its password which are needed when either Client or Server want to access to Caster. Mount point is simply a name of a specific connection in Caster, of course, between a certain Client and its Server. Likewise, IP address and a port of Caster PC are required for a communication link being established. Therefore, it would be more reliable if the IP address is static.

Secondly, NTRIP server is a software running in a PC or a microprocesser which communicates directly to NTRIP source. NTRIP source is a positioning module which corrects data from satellites and sends it to NTRIP server. In a further way, the purpose of NTRIP server is to reach for the correction data from base station and transmit it over internet to NTRIP caster. There are some crucial parameters at NTRIP server when connecting to Caster: mount point name and password of Caster, destination IP address-Caster IP address. Besides, there are other parameters such as input mode, output mode, baud rate, etc. which would be explained in detail in the Chapter 5 of this paper.

Last but not least, NTRIP client receives transmitted correction data from Caster and provides it to rover. Otherwise, the concept of Client is similar to Server including parameters expected from Caster in order to pick up data from it. Until now, there have been two versions of NTRIP. While NTRIP 1.0 is a stateless protocol, NTRIP 2.0 is more advanced with TCP/IP, RTSP/RTP, UDP protocol options. [16]

However, NTRIP 2.0 is not completely developed and should be used with thorough understanding about Internet Protocol. Therefore, in this project of building a RTK base station, NTRIP 1.0 is used instead.

# 4 Elements of NTRIP Base Station

In three previous chapters, the fundamental knowledge of high-precise positioning has been described. In general, the most worldwide range measurement methods are code-carrier (PRN) and phase carrier. Phase carrier's output is less error than PRN code method. However, it also takes more time to get into fixed mode. Based on these measurements, different types of precise positioning protocol have been developed. In the present days, one of the most efficient system is come to be known as NTRIP. In this chapter, two major factors contributing to the construction of the NTRIP base station-or RTK base station of this project would be discussed.

## 4.1 Necessary Software (BKG ntripserver)

BKG provides their software running in variety of Operating Systems. However, in this particular project, only the Linux x32 OS is going to be considered. BKG ntrip server is a free open source software which can be easily implemented on any PC.

NTRIP server and client are built based on HTTP client but they are specialized in GNSS data transmission. As discussed in Chapter 3.4, NTRIP Server plays a role as transmitting correction data from base station to NTRIP caster while NTRIP client picks up data from caster and sends it to rover. NTRIP server can capture a GNSS data stream from several methods, for instance: serial communication, IP server, NTRIP Version 1.0 version, etc. [16].

After getting data from NTRIP source, it can forward the stream to one of the following destinations: NTRIP Version 2.0 Caster via TCP/IP, NTRIP Version 2.0 Caster via RTSP/RTP, NTRIP Version 2.0 Caster via plain UDP, NTRIP Version 1.0 Caster[16].

In a detailed illustration, the program offers a variety of options for input configuration and the signatures come with them.

"-M" tells PC that input parameters are going to be entered. Integers from 1 to 6 are used to set input mode. "1" means input stream coming from Serial port, "2" means it is from an IP sever, "3" means File source, "4" and "5" is for SISNeT Data Server and UDP server respectively. Finally, "6" is used when input is from NTRIP Caster. Depending on which input mode is chosen, different sub-parameters are going to be considered.

In case "1" input mode, "-i" is to set address of serial input device. "-b" parameter sets input baud rate. "-f" is used to enter Name of initialization file send to input device. This is an optional parameter. When the other input modes chosen, there are similar parameters must be determined by users such as "-H" input host name and address, "-P" Input port, "-s" File Path, etc.

Likewise, "-O" initiates the output configuration with integer from 1 to 4 setting communication output mode with destination Caster.

"1": NTRIP Version 2.0 Caster in TCP/IP mode

"2"= rtsp: NTRIP Version 2.0 Caster in RTSP/RTP mode

"3" = ntrip1: NTRIP Version 1.0 Caster

"4" = udp: NTRIP Version 2.0 Caster in Plain UDP mode

Again, "3" mode is used in this project.

After that, the following parameters are required to be concerned. User must define "-a", address of destination caster. in the same ways, "p", destination caster port must be declared. A mountpoint, "-m" created at Caster is obligated to be filled. Destination user's name or ID, "-n", and password for upload stream to Caster, "-c", must be known by user. Finally, an optional source table record for NTRIP version 2.0 should be given. Here is an example of how to use BKG ntripserver in a Linux OS [16]:

./ntripserver -M 1 -i /dev/ttys0 -b 9600 -O 2 -a www.euref-ip.net -p 2101 -m MountPoint -n serverID -c serverPass

where "./ntripserver" is the command to start up BKG ntripserver.

Overall, BKG has supplied a free and intelligent software for engineers to access to the idea of transmitting GNSS signal over Internet.

## 4.2 Review of Components

### 4.2.1 Tracking Satellite Device- U-Blox ZED-F9P and C099-F9P module

ZED-F9P is a high precision GNSS device, which is created with the main purpose for RTK rover and base station. Nowadays, ZED-F9P is applied to variety of fields, such as: agriculture, professional sports, survey and mapping, etc. In addition, its size is extremely small and compact, which is only 17 x 22 x 2.4 mm [17.].

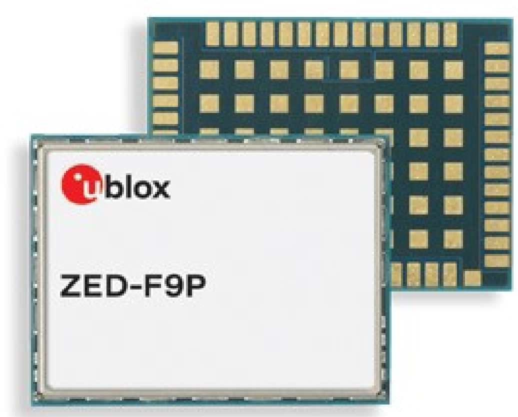



Figure 4: ZED-F9P module [18]

ZED-F9P can be configured in order to work in one of two modes: either RTK base station or RTK rover. It is able to deliver Positioning Signal with accuracy down to centimeters level. In a perfect environment- clear sky and good access to satellites, ZED-F9P can locate receivers with the offset of 1-3 cm. One of the reasons why ZED-F9P can achieve such an accuracy is that it supports a wide range of GNSS frequency. That is to say, ZED-F9P can collect most data types from variety of advanced satellite systems like

GPS, Galileo, GLONASS, BeiDou, QZSS. An additional feature making ZED-F9P widely applicable is a diversity of communication interfaces. While UART1 is the primary interface, ZED-F9P also provides optional UART2, USB, I2C and SPI ones. [18,4.]

Because only UART1 is used in the Base Station project of this paper, let's take a deeper look on how configuring it. As usual, there are some common parameters required to be considered by users. Firstly, the default baud rate of UART1 is 38400. However, a more international value 115200 should be used instead. Secondly, depending on user's application, they should alter NMEA message types which are enabled in default with GGA, GLL, GSA, GSV, RMC, VTG, TXT being activated. NMEA short for National Marine Electronics Association, is a standard allows marine electronic devices send their information to other marine devices or to computers. Different NMEA messages contain different kinds of information about their host device. Besides, there are raw Ublox messages-UBX and RTCM messages which should be studied by users in order to be configured accordingly to their application. Both input and output of UART1 have the same parameters. However, there are differences in standards of RTCM messages between themselves. Two of the tables below in figure 5 - extracted from the official manual of ZED-F9P [18,7-8]- would fully illustrate the difference.

| Message | Description |
|---|---|
| RTCM 1001 | L1-only GPS RTK observables |
| RTCM 1002 | Extended L1-only GPS RTK observables |

| Message | Description |
|---|---|
| RTCM 1003 | L1/L2 GPS RTK observables |
| RTCM 1004 | Extended L1/L2 GPS RTK observables |
| RTCM 1005 | Stationary RTK reference station ARP |
| RTCM 1006 | Stationary RTK reference station ARP with antenna height |
| RTCM 1007 | Antenna descriptor |
| RTCM 1009 | L1-only GLONASS RTK observables |
| RTCM 1010 | Extended L1-only GLONASS RTK observables |
| RTCM 1011 | L1/L2 GLONASS RTK observables |
| RTCM 1012 | Extended L1/L2 GLONASS RTK observables |
| RTCM 1033 | Receiver and antenna description |
| RTCM 1074 | GPS MSM4 |
| RTCM 1075 | GPS MSM5 |
| RTCM 1077 | GPS MSM7 |
| RTCM 1084 | GLONASS MSM4 |
| RTCM 1085 | GLONASS MSM5 |
| RTCM 1087 | GLONASS MSM7 |
| RTCM 1094 | Galileo MSM4 |
| RTCM 1095 | Galileo MSM5 |
| RTCM 1097 | Galileo MSM7 |
| RTCM 1124 | BeiDou MSM4 |
| RTCM 1125 | BeiDou MSM5 |
| RTCM 1127 | BeiDou MSM7 |
| RTCM 1230 | GLONASS code-phase biases |
| RTCM 4072.0, subtype 0 | Reference station PVT (u-blox proprietary RTCM Message) |
| RTCM 4072.1, subtype 1 | Additional reference station information (u-blox proprietary RTCM Message) |

Figure 5: List of RTCM messages supported by ZED-F9P module [18,7-8]

However, ZED-F9P is a mounted-on-board module. Therefore, it is not straightforward to be used. That is why Ublox company released a PCB with ZED-F9P implemented on itself, called C099-F9P. This GNSS board provide customers a more accessible user interface of ZED-F9P. Besides, C099-F9P also comes along with a Wifi and Bluetooth module, ODIN-W2. However, this function is not useful in the Base Station project, hence it is not introduced thoroughly in this paper. C099-F9P accepts 6-12 V DC on DC jack as a power supply. Similarly, the board can be powered by micro USB port or by 3.7 V Li-Po battery. [19,5.]

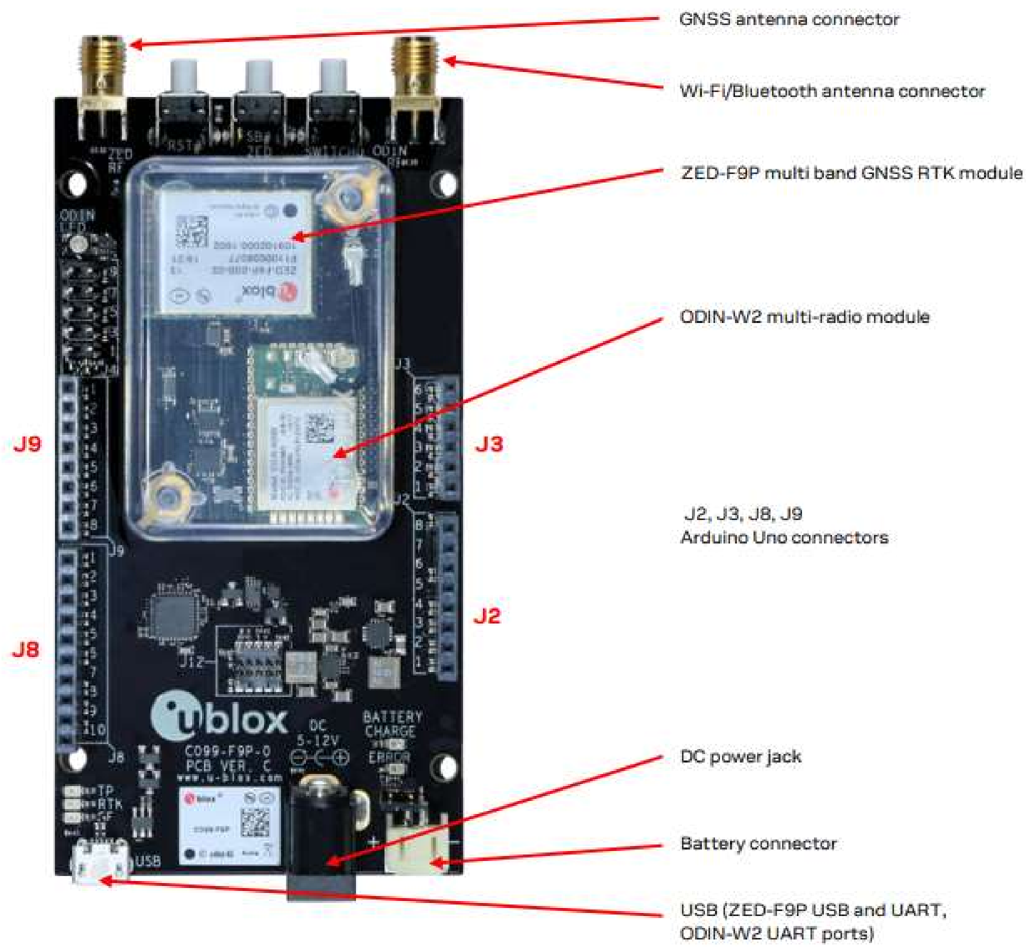



Figure 6: Overview of C099-F9P module [19,10]

Figure 6 shows a brief user interface of C099-F9P module. At the top left corner is a GNSS antenna connector. After connected, GNSS antenna should be placed on the ground plane provided by manufacturer or any area that is grounded properly. After C099-F9P is connected to a Laptop or PC, there are 3 COM ports installed by the driver. PC or laptop should have Internet connection during this process. The first COM port is for ODIN connection. ZED-F9P is the second COM port. The last COM port is connected directly to USB port of ZED-F9P. Use “Device Manager” on connected PC or laptop to check these COM ports.


Figure 7: List of COM ports of C099-F9P module on a Laptop

The above figure 7 shows COM port assignments of C099-F9P on connected laptop. Besides, there are three main LED indicators on the PCB.

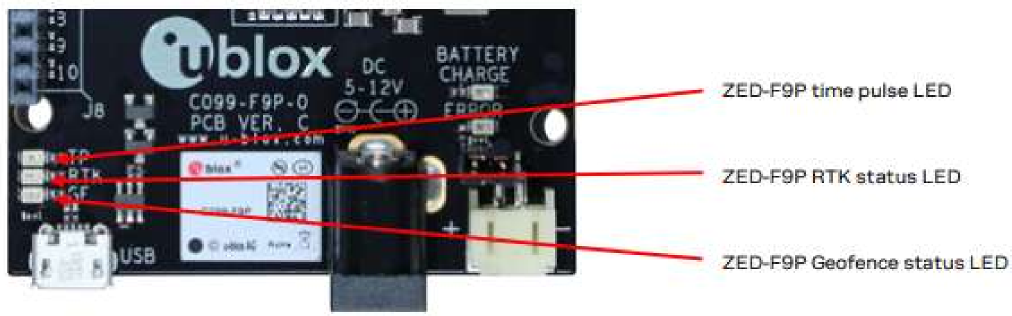



Figure 8:  Three main LED indicators on C099-F9P module [19,12]

When ZED-F9P receives RTCM messages and get into Float Mode, the RTK status LED will flash at the navigation rate (default=1 Hz) with yellow colour. When it reaches Fixed Mode, the LED is stable. Besides, there are less important indicators: Geofence and Time pulse LED [19,11.].

One more vital interface of C099-F9P is its Arduino header connections. The board provides 4 connectors based on Arduino mechanical function J2, J3, J8, J9. All the pins except for GND and Power properly function at 3.3V level. The following figure shows the pin assignments of these connectors [19,37.].

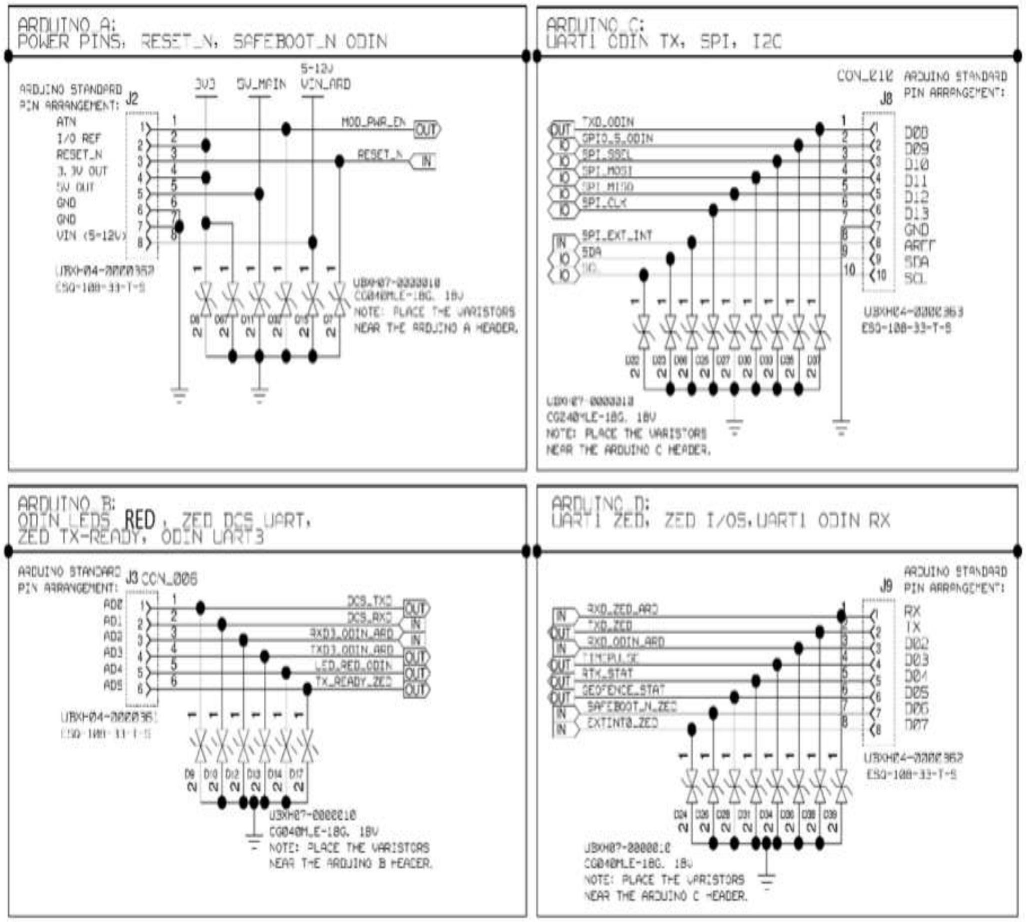



Figure 9: Arduino pin assignment on C099-F9P module [19,37]

### 4.2.2 Microprocessor – Beaglebone Black (BBB)

BBB, together with Rasberry pi, are the most famous microprocessors in the world. BBB runs on Debians which is a Linux-based Operating System. The 2 typical types of Debian are Graphical User Interface and Command-Line User Interface. As the names imply, it is logical that GUI Debians consumes more database of BBB than CUI. That is why CUI is more likely to be used in real-life projects. There are different versions of BBB, however, the most regularly used version nowadays is Beaglebone Black Rev C. This version has an 4GB eMMC storage. eMMC which is short for embedded Multi-Media Controller refers to one type of storage of Flash memory and its controller [20]. Due to its compact feature, eMMC can be found in many smartphones or other relating electronic devices.

BBB can be powered via USB or 5V DC connector and its maximum consumed current can be up to 1A. Customers should always make sure that their power supply to BBB meets the requirement especially when it is used in portable projects. The next picture illustrates the full hardware interface of BBB Rev C. [21.]

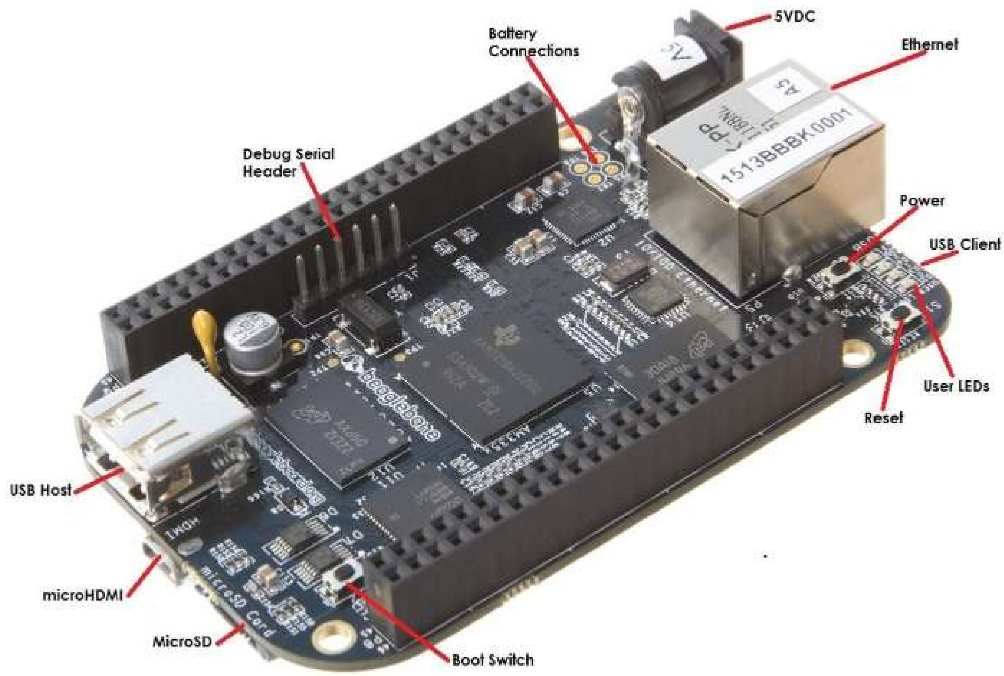



Figure 10: Overview of Beaglebone Black [21]

Besides, during process of coding and configuration for a certain system or project, BBB can be used as a Standalone Computer with connection to keyboard and mouse via its female USB port. In addition, BBB has a micro HDMI port allowing users displaying BBB with a screen, which completes itself as a computer. The following figure 11 describes what a standalone BBB computer might look like.

Figure 11: Illustration of Beaglebone Black as a computer [21]

Last but not least, BBB provides 2 IO connectors which are called P8 and P9, are aligned to two sides of the board. Each I/O pin has more than two working modes with being compatible to 3.3V. Besides, there are several fixed power supply pins including 5 V, 3.3 V and GND. These two common low voltages make the board more applicable. These I/O pins can be configured to be worked in different functions. Figure 12 and 13 below demonstrates some of BBB I/O functions. [20.]

| P9 | | | | P8 | | | |
|---|---|---|---|---|---|---|---|
| DGND | 1 | 2 | DGND | DGND | 1 | 2 | DGND |
| VDD_3V3 | 3 | 4 | VDD_3V3 | GPIO_38 | 3 | 4 | GPIO_39 |
| VDD_5V | 5 | 6 | VDD_5V | GPIO_34 | 5 | 6 | GPIO_35 |
| SYS_5V | 7 | 8 | SYS_5V | TIMER4 | 7 | 8 | TIMER7 |
| PWR_BUT | 9 | 10 | SYS_RESETN | TIMER5 | 9 | 10 | TIMER6 |
| GPIO_30 | 11 | 12 | GPIO_60 | GPIO_45 | 11 | 12 | GPIO_44 |
| GPIO_31 | 13 | 14 | EHRPWM1A | EHRPWM2B | 13 | 14 | GPIO_26 |
| GPIO_48 | 15 | 16 | EHRPWM1B | GPIO_47 | 15 | 16 | GPIO_46 |
| GPIO_5 | 17 | 18 | GPIO_4 | GPIO_27 | 17 | 18 | GPIO_65 |
| I2C2_SCL | 19 | 20 | I2C2_SDA | EHRPWM2A | 19 | 20 | GPIO_63 |
| EHRPWM0B | 21 | 22 | EHRPWM0A | GPIO_62 | 21 | 22 | GPIO_37 |
| GPIO_49 | 23 | 24 | GPIO_15 | GPIO_36 | 23 | 24 | GPIO_33 |
| GPIO_117 | 25 | 26 | GPIO_14 | GPIO_32 | 25 | 26 | GPIO_61 |
| GPIO_115 | 27 | 28 | ECAPPWM2 | GPIO_86 | 27 | 28 | GPIO_88 |
| EHRPWM0B | 29 | 30 | GPIO_112 | GPIO_87 | 29 | 30 | GPIO_89 |
| EHRPWM0A | 31 | 32 | VDD_ADC | GPIO_10 | 31 | 32 | GPIO_11 |
| AIN4 | 33 | 34 | GNDA_ADC | GPIO_9 | 33 | 34 | EHRPWM1B |
| AIN6 | 35 | 36 | AIN5 | GPIO_8 | 35 | 36 | EHRPWM1A |
| AIN2 | 37 | 38 | AIN3 | GPIO_78 | 37 | 38 | GPIO_79 |
| AIN0 | 39 | 40 | AIN1 | GPIO_76 | 39 | 40 | GPIO_77 |
| GPIO_20 | 41 | 42 | ECAPPWM0 | GPIO_74 | 41 | 42 | GPIO_75 |
| DGND | 43 | 44 | DGND | GPIO_72 | 43 | 44 | GPIO_73 |
| DGND | 45 | 46 | DGND | EHRPWM2A | 45 | 46 | EHRPWM2B |

Figure 12: 8 PWMs and Timers function on Beaglebone Black [22]

| P9 | | | | P8 | | | |
|---|---|---|---|---|---|---|---|
| DGND | 1 | 2 | DGND | DGND | 1 | 2 | DGND |
| VDD_3V3 | 3 | 4 | VDD_3V3 | GPIO_38 | 3 | 4 | GPIO_39 |
| VDD_5V | 5 | 6 | VDD_5V | GPIO_34 | 5 | 6 | GPIO_35 |
| SYS_5V | 7 | 8 | SYS_5V | GPIO_66 | 7 | 8 | GPIO_67 |
| PWR_BUT | 9 | 10 | SYS_RESETN | GPIO_69 | 9 | 10 | GPIO_68 |
| UART4_RXD | 11 | 12 | GPIO_60 | GPIO_45 | 11 | 12 | GPIO_44 |
| UART4_TXD | 13 | 14 | GPIO_50 | GPIO_23 | 13 | 14 | GPIO_26 |
| GPIO_48 | 15 | 16 | GPIO_51 | GPIO_47 | 15 | 16 | GPIO_46 |
| GPIO_5 | 17 | 18 | GPIO_4 | GPIO_27 | 17 | 18 | GPIO_65 |
| UART1_RTSN | 19 | 20 | UART1_CTSN | GPIO_22 | 19 | 20 | GPIO_63 |
| UART2_TXD | 21 | 22 | UART2_RXD | GPIO_62 | 21 | 22 | GPIO_37 |
| GPIO_49 | 23 | 24 | UART1_TXD | GPIO_36 | 23 | 24 | GPIO_33 |
| GPIO_117 | 25 | 26 | UART1_RXD | GPIO_32 | 25 | 26 | GPIO_61 |
| GPIO_115 | 27 | 28 | GPIO_113 | GPIO_86 | 27 | 28 | GPIO_88 |
| GPIO_111 | 29 | 30 | GPIO_112 | GPIO_87 | 29 | 30 | GPIO_89 |
| GPIO_110 | 31 | 32 | VDD_ADC | UART5_CTSN+ | 31 | 32 | UART5_RTSN |
| AIN4 | 33 | 34 | GNDA_ADC | UART4_RTSN | 33 | 34 | UART3_RTSN |
| AIN6 | 35 | 36 | AIN5 | UART4_CTSN | 35 | 36 | UART3_CTSN |
| AIN2 | 37 | 38 | AIN3 | UARR5_TXD+ | 37 | 38 | UART5_RXD+ |
| AIN0 | 39 | 40 | AIN1 | GPIO_76 | 39 | 40 | GPIO_77 |
| GPIO_20 | 41 | 42 | UART3_TXD | GPIO_74 | 41 | 42 | GPIO_75 |
| DGND | 43 | 44 | DGND | GPIO_72 | 43 | 44 | GPIO_73 |
| DGND | 45 | 46 | DGND | GPIO_70 | 45 | 46 | GPIO_71 |

Figure 13: 4 UARTs function on Beaglebone Black [22]

### 4.2.3 Internet Module (Quectel EvB Board and Quectel EG25-g)

Quectel EvB is an evaluation board (EvB) used to configure and develop all Quectel Mini Pcie modules. Pcie, abbreviated for Peripheral Component Interconnect Express, is a standard for high-speed communication between electronic components. The word mini just means one version of PCIE. Generally, Mini Pcie can be applied to many different types of component such as video and graphics cards in computer. In the Quectel's case, Mini Pcie implies to celular module or Internet module. The below figure which is original from the official "Quectel Mini PCIe EvB User Guide" shows a quick overview of the board [23].

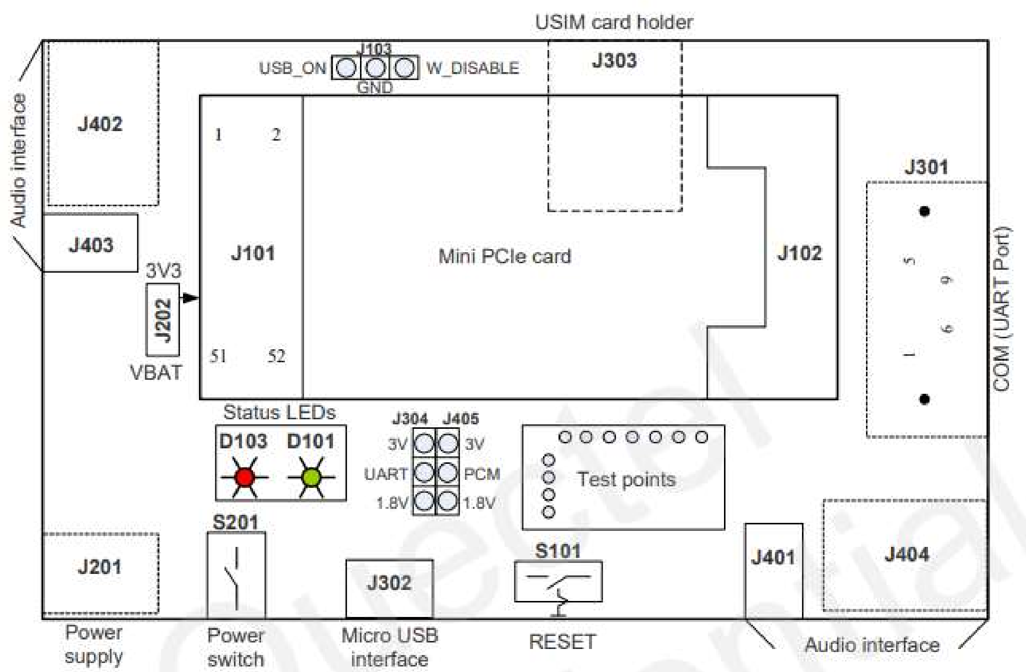



Figure 14: Overview of Quectel Mini PCIe EvB [23]

There are relatively a lot of interfaces on the board. However, only a few of them are regularly used. Power can be supplied via jack J201 with the typical 5V DC or via micro USB interface. While the main power supply is 5 V DC, the voltage Vbat supplying PCIe card is 3.3V. Vbat supply Mini PCIe card interface resided in the middle of EvB board. [23.]

Besides playing a role as a socket for power supply, micro USB can be used as an interface to access to Mini PCIe cards, which is the indispensable function of the board. Furthermore, switch S201 is to control the power supply and 2 LEDs D103, D101 indicate status of Vbat and Mini PCIe module respectively. Another vital interface is COM port providing UART connection to other devices. [23.] This feature is especially useful in this particular project as it is a method to provide internet to Beaglebone Black from Mini PCIe EG25-g Celular module. All celular generations of Quectel are small mounted-on-board modules. However, in order to be compatible with EvB board interface, they also produce PCIe card with a celular module mounted on the card.


Figure 15: Quectel EG25-G module

EG25-g is one of the newest Celular generations manufactured by Quectel recently. It is an LTE Cat 4 module specialized in IoT applications. LTE standing for Long-Term Evolution is referred as a standard for wireless communication for mobile devices in general which is similar to Some common term such as "4G" or "3G", etc. The detailed differences between these standards are not discussed here because it is not the main subject. LTE can be divided into several categories depending on specifications of each system such as uplink, downlink, etc. For example, LTE cat 4 has max downlink of 150 Mbits/s and uplink of 50 Mbits/s [24]. Further specifications and explanation can be found at Quectel official manual.

# 5 Construction of NTRIP Base Station

## 5.1 ZED-F9P Configuration

### 5.1.1 Get ZED-F9P Started.

First of all, C099-F9P can be powered by using USB cable to laptop. To add to it, external antenna provided by U-blox should be connected to "ZED-RF" female antenna port of the module. For now, hardware setup for C099-F9P is completed. Configuring functions of the module are necessary.

Ublox creates U-center software to configure and develop all of their Ublox modules. This is a free software and can be easily downloaded and installed from Ublox website. Firstly, ZED-f9p module can be powered and configuration interface can be created by connecting ZED module to a PC or laptop. Now, COM port assignment can be found in "Device Manager".

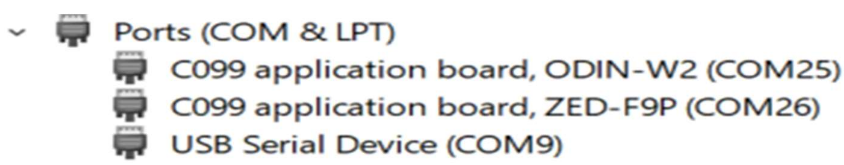



Figure 16: COM ports of C099-F9P on a laptop

In this case, COM25 is used for ODIN-W2 module's serial communication while ZED-F9P utilizes COM26. And COM9 is connected directly to USB port of ZED.

When using a new C099-F9P module, users may be required to upgrade firmware of ZED-F9P module first. This firmware can be found and downloaded on Ublox official web page. The next step for users is to open U-center and select the port assigned to ZED module. Under "Tools" >> "Firmware Update", the configuration should be modified as following [19,30].

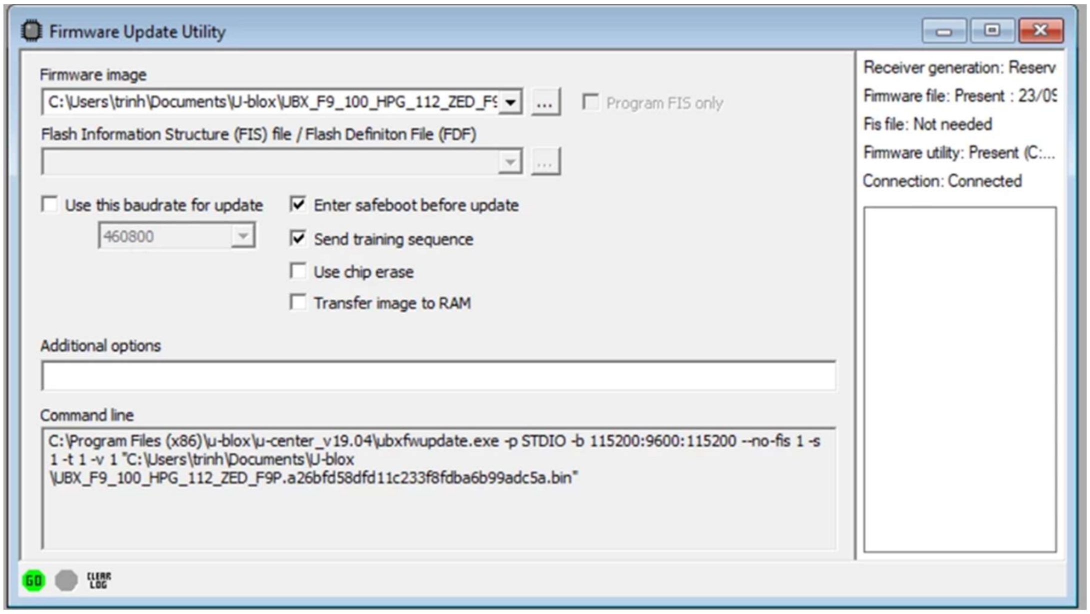



Figure 17: Illustration of updating ZED-F9P firmware

Where *Firmware image* is a box to load firmware file that has been downloaded in the previous step. Finally, green "Go" button on the left bottom corner would trigger the process of writing new firmware to ZED-F9P.

ZED-F9P is ready to be chosen a proper baudrate for ZED-F9P. The default value should be *38400*.


Figure 18: Illustration of a successful set-up C099-F9P

The ZED-F9P's baudrate in this example has been changed to a more universal value *115200* before. Therefore, *115200* is the chosen value here.

The green led on the bottom of U-center window indicates a connection is successfully established and next to it is COM port and baudrate information.

### 5.1.2. NTRIP Base Station Configuration

The next instruction shows how to configure C099-F9P working as a NTRIP base station source.

Under "Configuration view" >> "Port",*115200* baud rate should be chosen as this value is used worldwide. Similarly, under "Configuration view" >> "VALSET", Group "CFG-MSGOUT" and key name "CFG-MSGOUT-RTCM_3X" can configure function of UART1. Here are a recommended set of messages: *1005, 1074, 1084, 1094, 1124, 1230* [18,20-21]

"Add to list" would add these messages to UART1. Afterwards, value "1" ("10" for 1230) should be filled to each message. This value is updating rate of messages. Finally, "Send" button would activate the current configuration.

"Time Mode" is the final step of configuring C099-F9P as a NTRIP base station. There are two ways to set "Time Mode" for the base station: Survey-in and Fixed mode. The Fixed mode is used when approximate location of base station is already known. In contrast, Survey-in is used without information about base station location. Survey-in mode takes more time than "Fixed mode" to get a fix and precise location.

Here is an example to set up Survey-in mode [18,18.]:

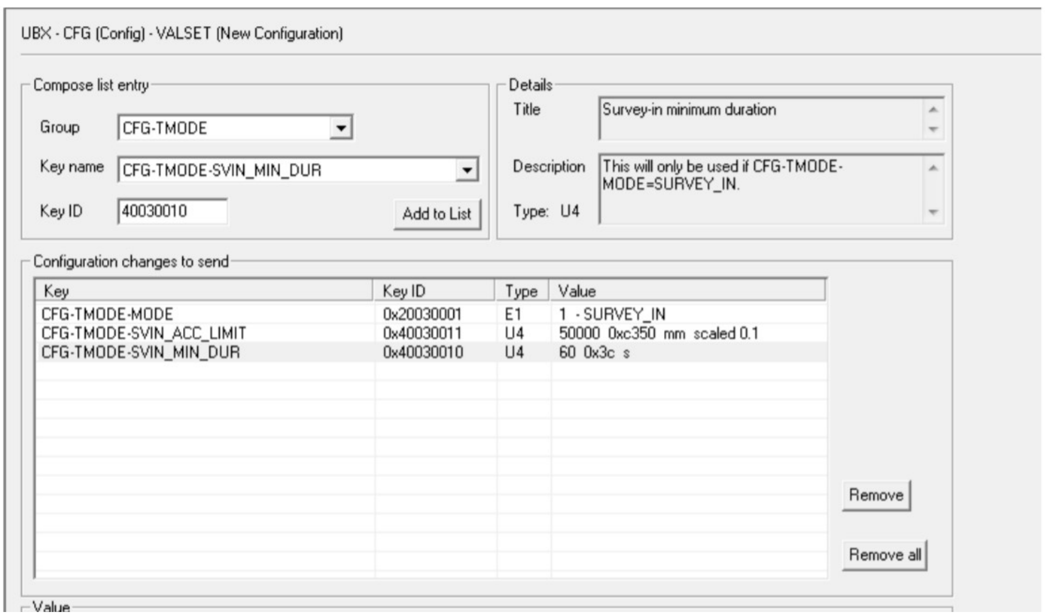



Figure 19: Example of Survey-in mode setup

In case Fixed mode is preferred in user’s application. It can be configured in the following way. Under "Configure view" >> "TMODE3", the approximate location and accuracy of the base should be entered (usually 3-to- 5-meter accuracy is good enough) [18,19.]:

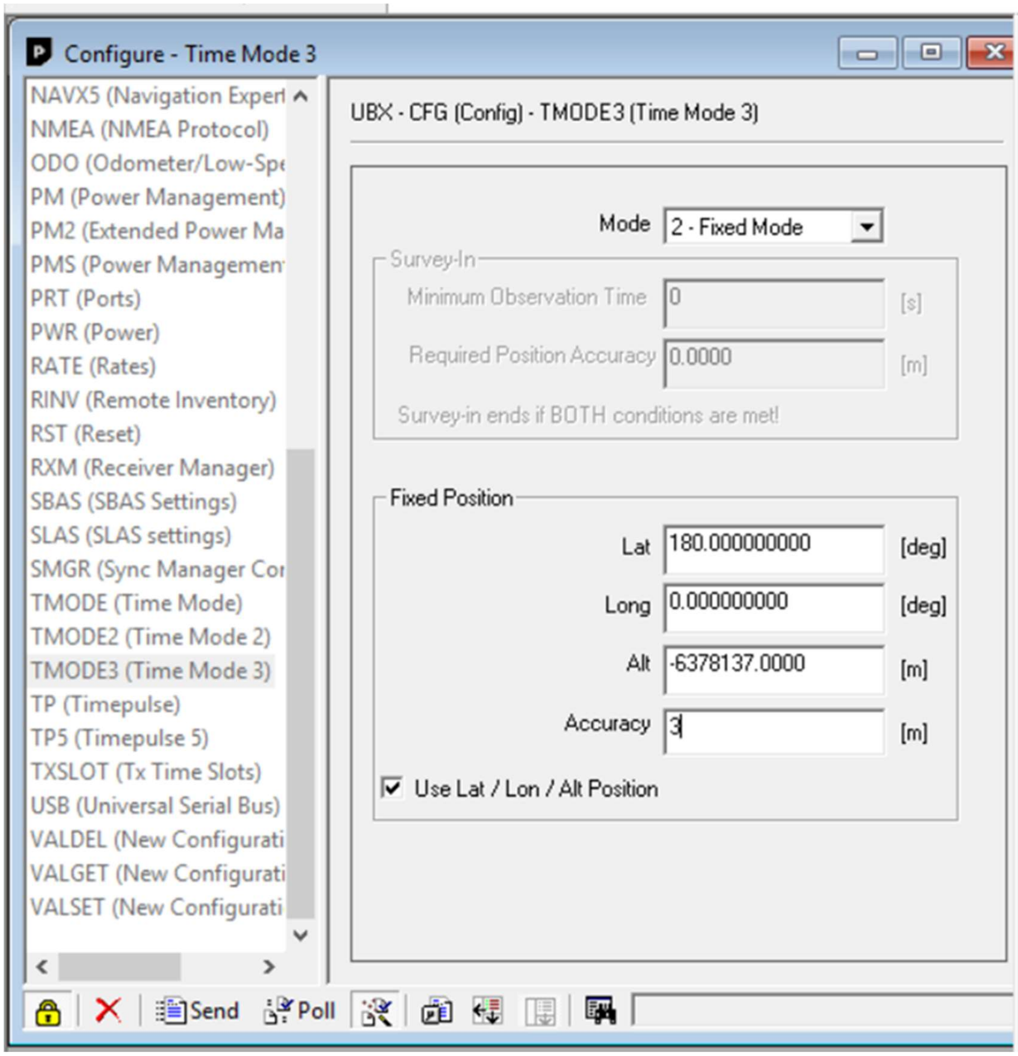



Figure 20: Example of Fixed mode setup

In order to, save the configuration, under "Configure" >> "Configuration", "Send" the "Save the configuration" would finish the task.

Note: U-Center also provides all NTRIP functions including ntrip server, ntrip-caster/server and it is easy to be manipulated. However, U-center is not supported on linux OS on which BBB is running. Then again, it has never been a smart idea to use a PC or Laptop inside an IoT product, that's why BBB and BKG ntrip software are chosen in this project instead.

## 5.2 Beaglebone Black and ZED-F9P connection

Even though NTRIP base station does not have a PC or laptop itself, in the whole NTRIP system, a separate computer is needed to run NTRIP Caster 24/7. Currently, the most famous Caster is SNIP caster because it has a free version which supports most of the crucial functions of a NTRIP Caster. The following steps would make BBB communicate to SNIP Caster

**Set up SNIP caster**

Under "Help" >> "Registration", instructions have been given to register for the free LITE version of SNIP. On "Caster and Clients" section, "Caster IP" and "Caster port" should be changed to the desired values. LITE version only allows 3 streams working at the same time. Therefore, it may be necessary to disable some streams on "Relay Stream" (They are not useful anyway). On "Push-In Streams" section, "Set Up" is used to change the password of mountpoint. (for LITE version, "Reserved Mountpoint" is not activated)

**BBB configuration**

In this tutorial, readers are assumed to have basic knowledge about Linux. First of all, BBB can be connected to a laptop in order to power up using USB cable. There is a clear and thorough instruction on getting started with beaglebone black on Beaglebone Black Tutorial website. After successfully setting up BBB, it is recommended to download *Putty* software to laptop which allows PC to communicate to or control its connected device, in this case, BBB. Here is the interface of *Putty* software:

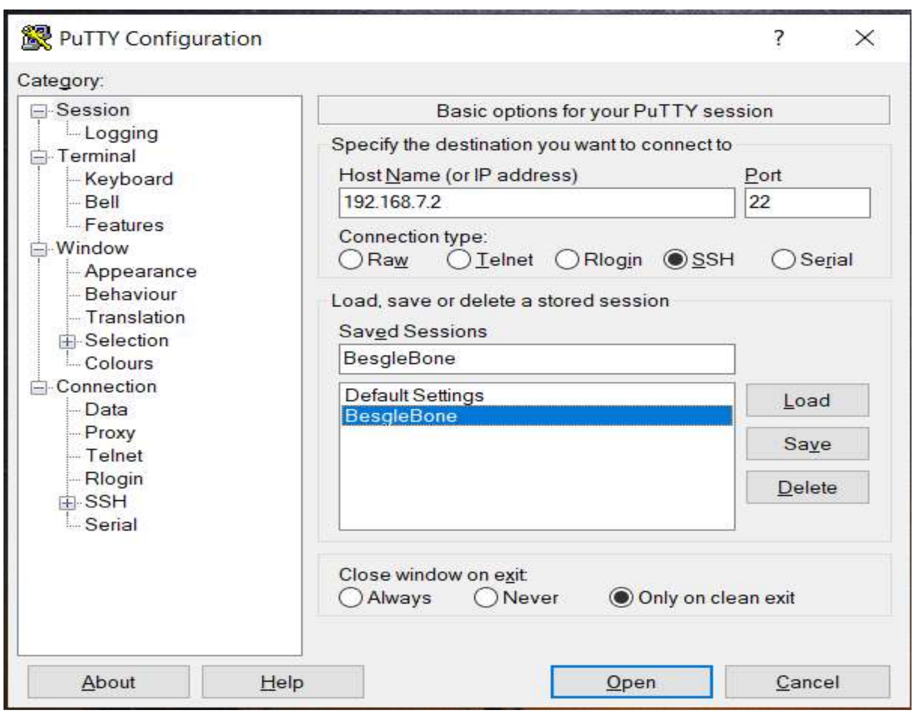



Figure 21: Putty Login Interface

After a valid “Host Name” is entered, a new dark interface would show up like this


Figure 22: Putty User Interface

At "Login as", “User Name” can be typed as "Debian". Next it would request a password for it, which is "temppwd". This would be a successful access looks like:

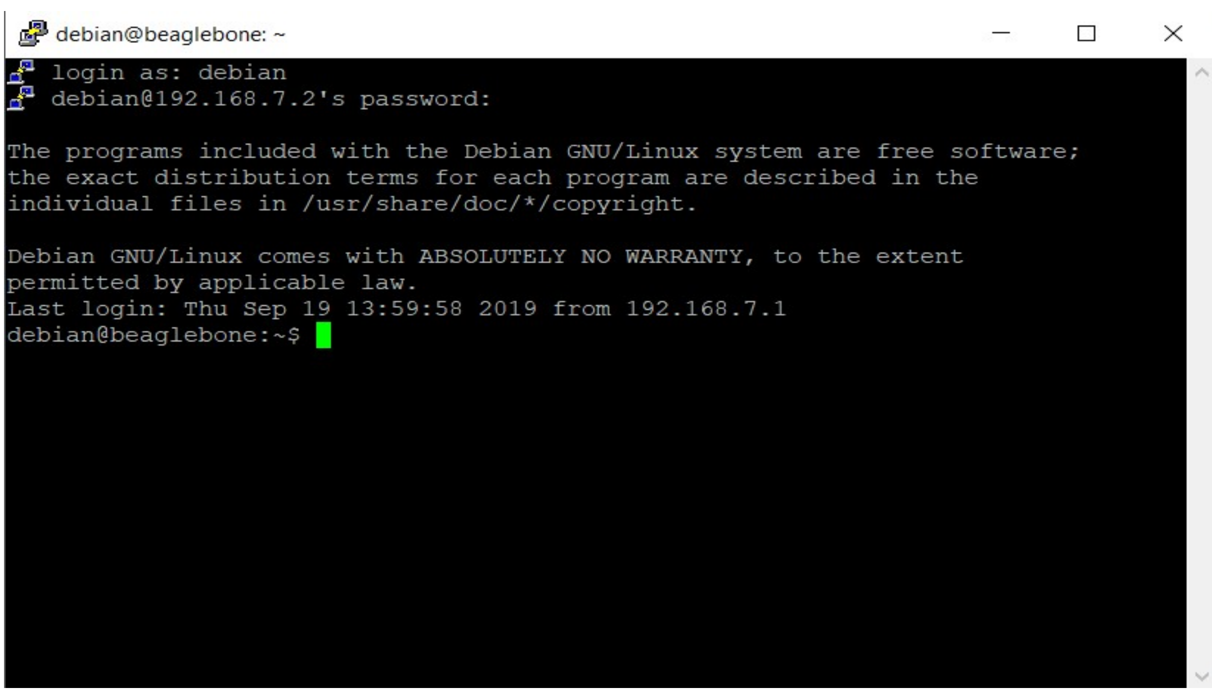



Figure 23: A successful login to “Debian”

In order to reduce confusion, during BBB configuration, **bold** letters refer to commands and *Italic* letters refer to texts modified or added to files or names of files.

It is a good start to activate UART interface of BBB on boot, which means that every time BBB is turned on, UART interface will be activated automatically.

A script is created to configure BBB to set up the UART pins with the command and scripts as shown in appendix 1.

The file should be executable for all users:

**chmod 755 /usr/local/sbin/setTty.sh**

A service file is created so that it can be run on boot:

**nano /lib/systemd/system/setTty.service**

*[Unit]*

*Description=Configure pins to enable ttyS4, ttyS2, ttyS1 as a UART*

*After=syslog.target network.target*

*[Service]*

*Type=simple*

*ExecStart=/usr/local/sbin/setTty.sh*

*[Install]*

*WantedBy=multi-user.target*

Finally, the service can be enabled to run on boot

**systemctl enable setTty.service**

After rebooting, UART1 UART2 UART4 will be activated with the locations as shown in the figure 12. Only one of the three UARTs (in this case UART2) is required to connect to ZED-F9P on C099-F9P. Here is the Arduino interface of the module. J9.1 is the Receiving port of ZED-F9P while J9.2 is the Transmitting port of ZED-F9P.


Figure 24: Arduino Pin Interface on C099-F9P [19,37]

Now Receiving port of UART2 should be connected to Transmitting port of ZED-F9P while Transmitting port of UART2 is connected to Receiving port of ZED-F9P. It is also important to connect Ground pins of BBB and C099-F9P together. A serial connection between BBB and ZED.F9P is accomplished now.

## 5.3 BKG Ntripserver on Beaglebone Black

Now it is compulsory to provide Internet to BBB. In this example, BBB is going to share Internet with laptop via USB connection after executing a few commands. Firstly, under "Network connections" inside "Network and Internet" on the laptop, "allows other network users to connect through this computer's internet connection" would allow laptop sharing internet connection to connected devices. And "Ethernet" of BBB, in this case "Ethernet 3" should be chosen.

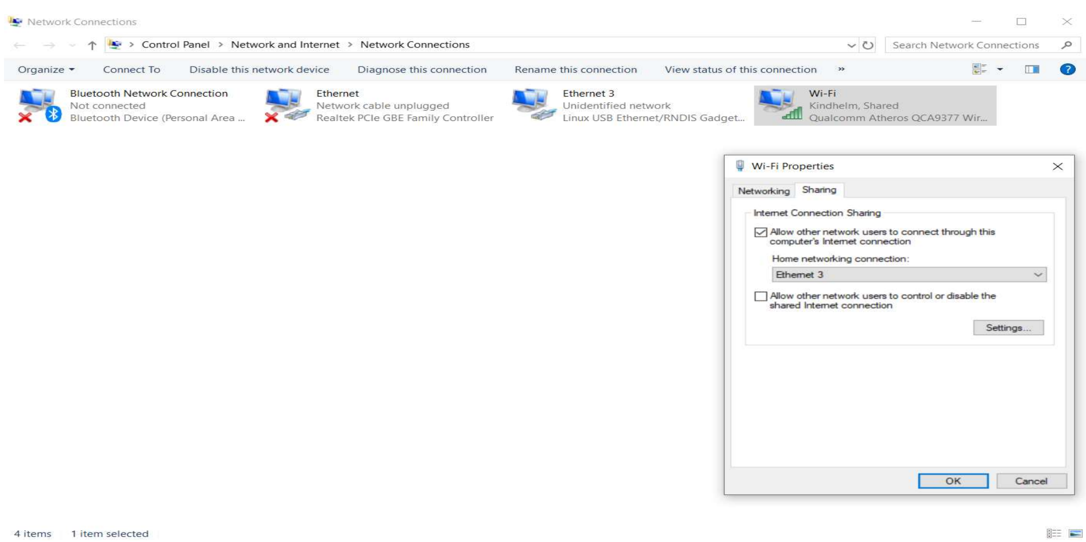



Figure 25: Sharing Internet option on Windows

Figure 25 shows an interface of how to share internet from laptop to its connected device. Also, IP4's address of Ethernet 3 should be changed to be automatic

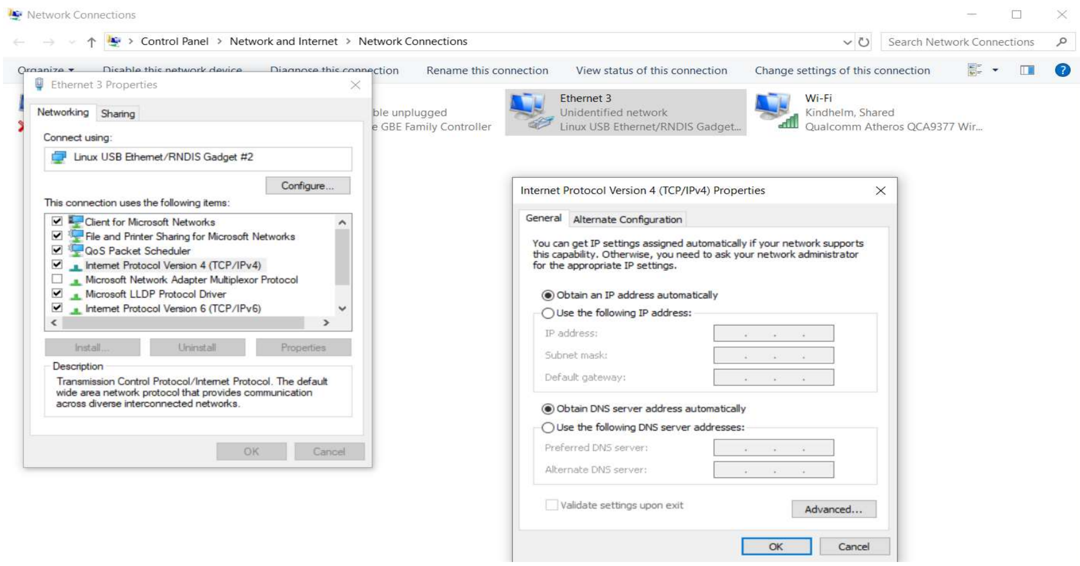



Figure 26: Set IP4 address of Beaglebone Black to be automatic

It is recommended to choose "Obtain an IP address automatically" and "Obtain DNS server address automatically" as it shown in figure 26. Typing in *Putty* the following commands and scripts would complete Internet connection process of BBB.

**sudo /sbin/route add default gw 192.168.7.1**

**sudo nano /etc/resolv.conf**

*nameserver 8.8.8.8*

It is important to save and exit **nano** interface.

Now, pinging "Google.com" would reply if Internet connection is established. If nothing happens, there is a high chance that laptop deny sharing Internet to BBB. To solve this, under *Windows Firewall -> Advanced Settings -> Inbound Rules*, *File and Printer Sharing (Echo Request....)* should be enabled

Next step is to download and install *rtcm-ntrip* software to beaglebone black. However, subversion (svn) software is needed to be installed first. SVN is a software used to monitor changing of source codes and other kinds of files. Similarly, the following command would do the job:

**sudo apt-get update**

**sudo apt-get install subversion**

Everything should be ready to install *rtcm-ntrip* software now. The next command is used to download the software [24]:

**svn checkout --username guest --password guest https://software.rtcm-ntrip.org/svn/trunk**

It may take a few minutes to completely download the whole package. After it is finished downloading, a *trunk* folder is created.


Figure 27: A new *trunk* folder is created after installing rtcm-ntrip software

There are variety of software inside this folder including the required *ntrip-server* one. Access to this folder and type **ls,** the whole packages would show up.

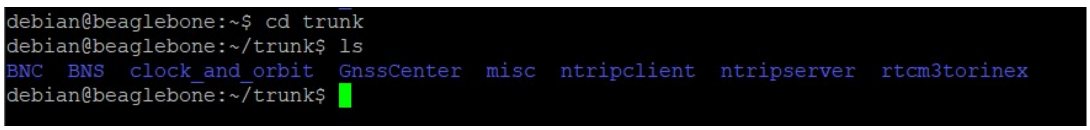



Figure 28: Packages inside *trunk* folder

However, only *ntrip-server* is concerned in this project. Accessing to *ntripserver* folder and typing **make** would install the software itself [25].

Every necessary software has been installed so far, which means it is ready to configure BBB by now.

### **Configure NTRIP server on BBB**.

The following steps would show how to transmit data from serial port 1 (UART1) of BBB to a far-away caster [25]

Directory trunk/ntripserver should be accessed on BBB.

**sudo nano startntripserver.sh**

*while true; do ./ntripserver -M 1 -i /dev/ttys1 -b 115200 -O 3 -a 192.168.100.80 -p 2101 -m Mount2 -c serverPass; sleep 60; done*

Where:

-M: input mode. "1" is serial mode

-i: serial connection of input stream. /dev/ttys1 means input from UART1 of BBB.

-b: baud rate of the base connecting to BBB.

-O: output mode. "3" is NTRIP1 mode.

-a: destination address. "192.168.100.80" is th IP address of the computer running SNIP in this example.

-p: port number to communicate to caster (check the "Caster Port" of SNIP)

-m: mount point name. (Because LITE SNIP does not support reserved mount points, this "-m" can be anything)

-c: password to mount point. (Check password of "Set Up" on "Push-In Stream" of SNIP)

After that, command **sudo ./startntripserver.sh** would start NTRIP server.

With the same method as activating UART on boot, appendix 2 can help ntrip-server run automatically.

The ntrip server should be working after BBB is rebooted

To stop the service, command: **systemctl stop StartServer.service** is used.

The point of this project is to convert the idea of NTRIP base station to a draft version in real life. That is why there are a lot of required developments in order to convert this project into a commercial product.

## 5.4 Quectel EG25-G Configuration

For the reason of convenience, sharing Internet to laptop is an approach to configure or running BBB in some testing cases. However, in a commercial product, base station still needs its own internet module. This section introduces how to provide Internet to BBB with EG25-G module by using an open source script called *fona*

In this project, a Saunalahti SIM card is used as an Internet source. Firstly, PIN number of SIM card is disabled so that BBB can easily connected to Quectel module. This step should be easy, there are a lot of solutions for this on Google.

After setting up EG25-G and its Control Board, the following command and scripts would create a point to point connection between EG25-G and BBB [26].

**apt-get update**

**apt-get upgrade**

**cd /opt/scripts/tools/**

**./update_kernel.sh**

**reboot**

COM port of BBB should be connected to COM port of Quectel Evaluation board. Also EG25-G module is inserted to its evaluation board (EvB) by now.

**cd /etc/ppp/peers/**

**wget https://raw.githubusercontent.com/adafruit/FONA_PPP/master/fona**

**sudo nano fona**

The sixth line of the script is changed to:

*connect "/usr/sbin/chat -v -f /etc/chatscripts/gprs -T internet.saunalahti"*

*internet.saunalahti* is the APN of Saunalahti SIM card.

The next command line is changed to:

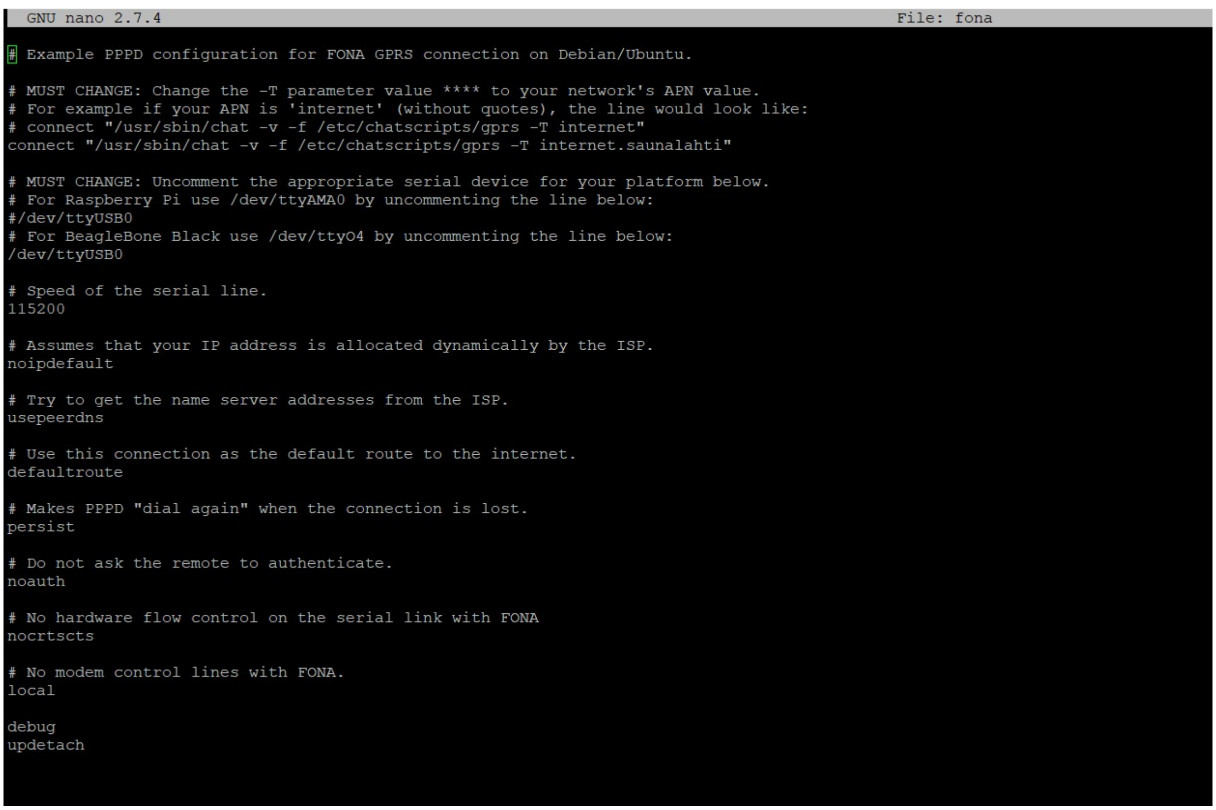
*/dev/ttyUSB0*

At the end of file:

*debug*

*updetach*

The file should look similar to this



```
GNU nano 2.7.4                                                          File: fona

# Example PPPD configuration for FONA GPRS connection on Debian/Ubuntu.

# MUST CHANGE: Change the -T parameter value **** to your network's APN value.
# For example if your APN is 'internet' (without quotes), the line would look like:
# connect "/usr/sbin/chat -v -f /etc/chatscripts/gprs -T internet"
connect "/usr/sbin/chat -v -f /etc/chatscripts/gprs -T internet.saunalahti"

# MUST CHANGE: Uncomment the appropriate serial device for your platform below.
# For Raspberry Pi use /dev/ttyAMA0 by uncommenting the line below:
#/dev/ttyUSB0
# For BeagleBone Black use /dev/ttyO4 by uncommenting the line below:
/dev/ttyUSB0

# Speed of the serial line.
115200

# Assumes that your IP address is allocated dynamically by the ISP.
noipdefault

# Try to get the name server addresses from the ISP.
usepeerdns

# Use this connection as the default route to the internet.
defaultroute

# Makes PPPD "dial again" when the connection is lost.
persist

# Do not ask the remote to authenticate.
noauth

# No hardware flow control on the serial link with FONA
nocrtscts

# No modem control lines with FONA.
local

debug
updetach
```

Figure 29: Configuration inside *fona* file

The above file has another detached file *gprs* which should be modified as well.

**sudo nano /etc/chatscripts/gprs**

change *OK AT+CGDCONT=1,"IP","\T","",0,0*

to *OK AT+CGDCONT=1,"IP","\T"*

In order to turn on the PPPD connection, **pon fona** is used.

"fona" has command to unlock SIM card with PIN numbers as well. Still, it is recommended that PIN numbers should always be unlocked or disabled.

In addition, “fona” needs to be activated on boot as well.

**sudo nano /etc/network/interfaces**

At the bottom of the file, the next line is added:

*auto fona*

*iface fona inet ppp*

*provider fona*

Every configuration required is properly done by now. After the whole system being, the base station should be running by itself.

## 6 Future Development and Conclusion

In general, the base station constructed in this paper satisfies the primary theory of a ntrip system. Despite that, as a commercial product needs to make customer experience comfortable, there are some crucial criteria the current version has been lacking and should be developed in the future.

One of the most important things is portable functionality. Currently, the base station is still being powered by a laptop, while it should have its own power supply such as battery. This power supply should be as small as possible so that the product can be easily carried around, while its capacity must be big enough for the system runs on its own to at least reach to its FIXED mode, which could take up to 8-12 hours. However, the first thing before choosing a suitable power supply is, obviously, calculating and measuring power consumption of the base station.

The second improvement should be made is UI or User Interface. Customers should be able to control the whole system via some buttons implemented outside of the box containing the base station or via a software which could be chosen to associate with the station of customers. An additional key thing should be notified is that Beaglebone Black is basically a computer. Therefore, it should be turned off properly by using command in control terminal of BBB or "Power" button on BBB itself or BBB may be stuck with programs it is running at the moment when it shuts down. However, these two methods may be inconvenient for customers. A shutdown method should be less complicated for customers to power off their base station. An external button connected to internal shutdown signal of BBB is a straightforward solution.

To put it to a nutshell, this paper has explained some fundamental knowledges about Precise Positioning. To that end, one of the most universal protocol and system is called NTRIP. Basically, an NTRIP system contains a caster, one or more base stations and clients. NTRIP base station and NTRIP client communicate to each other via their NTRIP caster. In addition, a comprehensible instruction has been offered in order to design a simple version of NTRIP base station.

## 7 References

1. **NASA.** https://www.nasa.gov/. *What is a Satellite.* [Online] [Accessed: 10. 10 2019.] https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-a-satellite-58.html.

2. **European Global navigation Satellites system Agency(GSA).** https://www.gsa.europa.eu/. *GNSS Downstream Market.* [Online] 15. 10 2019. [Accessed: 10. 11 2019.] https://www.gsa.europa.eu/market/gnss-market.

3. **Seeker.** https://www.seeker.com/. *How Satellites Track Your Exact Location.* [Online] [Accessed: 10. 10 2019.] https://www.seeker.com/how-satellites-track-your-exact-location-1792728340.html.

4. **Merlo Farming Group.** http://www.merlofarminggroup.com/. *Agri View: Driverless Tractors.* [Online] Merlo Farming Group. [Accessed: 10. 10 2019.] http://www.merlofarminggroup.com/agri-view-driverless-tractors.

5. **Trimble.** https://www.trimble.com/. *Code-Phase GPS vs Carrier-Phase GPS .* [Online] [Accessed: 10. 10 2019.] https://www.trimble.com/gps_tutorial/sub_phases.aspx

6. **Trimble.** https://www.trimble.com/. *Pseudo Random Code.* [Online] [Accessed: 10. 10 2019.] https://www.trimble.com/gps_tutorial/sub_pseudo.aspx

7. **European Space Agency.** https://gssc.esa.int/navipedia/index.php/Main_Page. *GNSS Signal.* [Online]
[Accessed: 10. 10 2019.] https://gssc.esa.int/navipedia/index.php/GNSS_signal

8. **NovAtel Inc.** https://www.novatel.com/. *An Introduction to GNSS->Chapter 5 - Resolving Errors » Precise Point Positioning (PPP) .* [Online] [Accessed: 10. 11 2019.] https://www.novatel.com/an-introduction-to-gnss/chapter-5-resolving-errors/precise-point-positioning-ppp/.

9. **Jet Propulsion Laboratory.** https://www.jpl.nasa.gov/. *Glossary-Ephemeris.* [Online] [Accessed: 10. 11 2019.] https://cneos.jpl.nasa.gov/glossary/ephemeris.html.

10. **Penn State University.** https://www.psu.edu/. *Precise Point Positioning.* [Online] [Accessed: 10. 11 2019.] https://www.e-education.psu.edu/geog862/node/1841.

11. **INSIDE GNSS MAGAZINE.** https://insidegnss.com/. *Finding the Right Algorithm* [Online] [Accessed: 10. 11 2019.] https://insidegnss.com/finding-the-right-algorithm/.

12. **Kairos Autonomi.** http://www.kairosautonomi.com/. *GPS Correction Comparisons – RTK vs DGPS* [Online] [Accessed: 11. 11 2019.] http://www.kairosautonomi.com/uploads/files/129/Bulletin---RTK-vs-DGPS-010400.pdf

13. **NovAtel Inc..** https://www.novatel.com/ *An Introduction to GNSS->Chapter 5 - Resolving Errors » Real-Time Kinematic (RTK)* [Online] [Accessed: 10. 11 2019.] https://www.novatel.com/an-introduction-to-gnss/chapter-5-resolving-errors/real-time-kinematic-rtk/

14. **Radio Technical Commission for Maritime Services (RTCM).** https://www.rtcm.org/ *About Us* [Online] [Accessed: 10. 11 2019.] https://www.rtcm.org/about-us

15. **SNIP.** https://www.use-snip.com/ *SNIP Knowledge Base* [Online] [Accessed: 10. 11 2019.] https://www.use-snip.com/kb/knowledge-base/question-what-is-an-ntrip/

16. **Bundesamt für Kartographie und Geodäsie (BKG)** https://igs.bkg.bund.de/index/index/ *source:ntrip/trunk/ntripserver/README* [Online] [Accessed: 12. 10 2019.] https://software.rtcm-ntrip.org/browser/ntrip/trunk/ntripserver/README

17. **Ublox.** https://www.u-blox.com/en *ZED-F9P module* [Online] [Accessed: 10. 11 2019.] https://www.u-blox.com/en/product/zed-f9p-module

18. **Ublox.** https://www.u-blox.com/en *ZED-F9P module-u-blox F9 high precision GNSS module Intergration Manual* [Accessed: 10. 11 2019.] https://www.u-blox.com/sites/default/files/ZED-F9P_IntegrationManual_%28UBX-18010802%29.pdf

19. **Ublox.** https://www.u-blox.com/en *C099-F9P Application board (rev. C), ODIN-W2 connectivity SW User guide* [Accessed: 10. 11 2019.] https://www.u-blox.com/sites/default/files/C099-F9P-AppBoard-ODIN-W2-CSW_UserGuide_%28UBX-18055649%29.pdf

20. **YourDictionary.** [Online] https://www.yourdictionary.com/value-added-service. [Accessed: 10. 11 2019.]

21. **beagleboard.org.** https://beagleboard.org/black *System reference manual* [Online] [Accessed: 10. 11 2019.]https://github.com/beagleboard/beaglebone-black/wiki/System-Reference-Manual

22. **beagleboard.org.** https://beagleboard.org *BeagleBone 101* [Online] [Accessed: 10. 11 2019.] https://beagleboard.org/Support/bone101

23. **Quectel.** https://www.quectel.com/ *Mini PCIe EVB Kit* [Online] [Accessed: 10. 11 2019.] https://www.quectel.com/product/minievb-Quectel-Mini-PCIE-EvB-User-Guide

24. **Bundesamt für Kartographie und Geodäsie (BKG)** https://igs.bkg.bund.de/index/index/ Welcome to Open Source Software development for Ntrip [Online] https://software.rtcm-ntrip.org/ [Accessed: 10. 11 2019.]

25. **Bundesamt für Kartographie und Geodäsie (BKG)** https://igs.bkg.bund.de/index/index/ *ntripserver* [Online] https://software.rtcm-ntrip.org/browser/ntrip/trunk/ntripserver [Accessed: 10. 11 2019.]

26**. Digikey** https://www.digikey.fi/en/maker *Unboxing and setup of the Cellular BeagleBone Black IoT Kit* [Online] https://www.digikey.fi/en/maker/blogs/cellular-beaglebone-iot-kit [Accessed: 10. 11 2019.]

**Appendix 1 Set up UART Pins on Beaglebone Black**

**sudo nano /usr/local/sbin/setTty.sh**

*#!/bin/sh*

*config-pin p9.11 uart*

*config-pin p9.13 uart*

*stty -F /dev/ttyO4 sane*

*#!/bin/sh*

*config-pin p9.21 uart*

*config-pin p9.22 uart*

*stty -F /dev/ttyO2 sane*

*#!/bin/sh*

*config-pin p9.24 uart*

*config-pin p9.26 uart*

*stty -F /dev/ttyO1 sane*

**Appendix 2 Run Ntripserver Automatically**

**nano /usr/local/sbin/StartServer.sh**

*#!/bin/sh*

*cd /home/debian/trunk/ntripserver*

*sudo ./startntripserver.sh*

**chmod 755 /usr/local/sbin/StartServer.sh**

**sudo nano /lib/systemd/system/StartServer.service**

*[Unit]*

*Description=Start NTRIP server*

*After=syslog.target network.target*

*[Service]*

*Type=simple*

*ExecStart=/usr/local/sbin/StartServer.sh*

*[Install]*

*WantedBy=multi-user.target*

**systemctl enable StartServer.service**

**systemctl start StartServer.service**