



HAL
open science

5G Positioning And Hybridization With GNSS Observations

Romain Crapart, Roc Maymo-Camps, Benoit Vautherin, Jani Saloranta

► **To cite this version:**

Romain Crapart, Roc Maymo-Camps, Benoit Vautherin, Jani Saloranta. 5G Positioning And Hybridization With GNSS Observations. ITSNT 2018, International Technical Symposium on Navigation and Timing, Oct 2018, Toulouse, France. 10.31701/itsnt2018.10 . hal-01942264

HAL Id: hal-01942264

<https://enac.hal.science/hal-01942264>

Submitted on 5 Dec 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

5G positioning and hybridization with GNSS observations

R.Crapart, *Telespazio*

R.Maymo-Camps, *Telespazio*

B.Vautherin, *Thales Alenia Space*

J.Saloranta, *University of Oulu*

Email:

romain.crapart@telespazio.com

roc.maymo-camps@telespazio.com

benoit.vautherin@thalesaleniaspace.com

jani.saloranta@oulu.fi

BIOGRAPHIES

Roc Maymo-Camps has had engineering masters by Escola Tècnica Superior d'Enginyeria Industrial de Barcelona (UPC) and ENAC (2007). He has been working at Telespazio for over 10 years in the navigation department.

Benoit Vautherin received his engineering degree from Ecole supérieure d'électricité, Metz, France, in 2015, and his MSc degree in space science and engineering from University College London, United Kingdom, in 2015. He joined Thales Alenia Space, Toulouse, France, in April 2015. Since then, he has been working as a navigation and data collect system engineer on many European and national R&D projects.

M.Sc Jani Saloranta is a PhD student at University of Oulu, Finland. He received his Master's degree in Mathematics (Group Theory) with minors from Statistics and Computer Sciences from University of Oulu in 2008. Since 2009 he has been a research scientist at Centre for Wireless Communications, University of Oulu, Finland. Since 2012 he is working towards his PhD degree from the title of Semantic Positioning in Department of Communications Engineering, University of Oulu, Finland.

Romain Crapart received his engineering degree from the Institut Supérieur de l'Aéronautique et de l'Espace ISAE (ENSICA course) in 2016. He joined Telespazio France in 2018 in the navigation department and is working as GNSS engineer for mobile and space applications.

ABSTRACT

The present paper depicts the tests and experimentations that have been carried out to show how GNSS and 5G can be used to improve positioning performance. In this frame, the design made during the 5G-Champion project has led to a solution combining both positioning systems in different environments to show in which cases one solution is better than the others and in which cases they can be complementary. The experimentations show the interest of

GNSS in open-sky and rural areas where 5G base stations will not be close to the user and will not be able to provide accurate positioning data. On the other extreme, in canyons and urban environments where buildings and multipath abundant can mask many satellites, the inclusion of 5G positioning data from stations that tend to be close to the user can improve the performance. At the end of this paper, a table summarizes the performance improvements, namely the accuracy and availability. Moreover, PPP solutions have been computed in order to see the benefits of PPP and 5G solutions combined.

1 INTRODUCTION

The paradigm of ubiquitous location information has risen a requirement for hybrid positioning methods, as a continuous data location cannot be provided by a single wireless system. Thus, such hybrid methods have interested the research community. Different joint techniques accounting different data sources and/or types have been proposed, *e.g.* coupling GNSS with vision sensors (Takasu & Yasuda, 2008) or inertial sensors (Angrisano, 2010). Nevertheless, the upcoming fifth generation (5G) networks jointly with Global Navigation Satellite System (GNSS) are still to be investigated.

It is expected that 5G positioning will be able to provide more precise location and enhanced availability in all kinds of environments, especially urban canyons, where most GNSS signals are blocked and suffer from severe multipath conditions. The 5G observations can be added to both single and precise point positioning (PPP) GNSS solutions to improve positioning performance.

The work was carried out during the EU-Korean "5GCHAMPION" project (Mueck & et.al., 2016). The paper is organized as follows.

- In Section 2, the objectives of the work are explained.
- In Section 3, the research methods and the presented objectives are discussed.
- In Section 4, the technologies and methods are explained from the positioning point of view for the

proposed hybrid 5G–GNSS method and infrastructure.

- Then in Section 5, results based on simulations and real life measurements are presented,
- And finally, in Section 6 concluding remarks are given.

2 OBJECTIVES

This study has three main objectives:

- Assess the positioning performance of the mm-Wave technology.
- Assess the benefit of 5G positioning over known GNSS positioning methods.
- Assess the positioning performance of the hybridized mm-Wave/GNSS solution

3 METHOD

The fulfillment of the objectives is done in two phases.

First, each solution is described to provide a technical understanding and to assess preliminary performance of each technology.

Second, a testing phase is provided with definition of Key Performance Indicators (KPI) and test cases. Then the test cases are executed and post-processed to assess the performance of each solution in real life.

4 TECHNOLOGY DEFINITION

4.1 mm-Wave Positioning

The millimeter wave (mmWave) technology¹ is considered as one of the key properties of the 5G communication networks (Saloranta & Destino, 2017). The exact definition of mmWave states a frequency band of 30 – 300 GHz; a relaxed definition e.g. from 23 – 32 GHz bands is considered in literature. This technology mainly brings the use of high data rate and the use of beamforming feature via large antenna arrays (Kutty & Sen, 2016). Such feature is used for the angle of arrival (AOA) positioning method. Furthermore, the characteristic of the mmWave channel is sparsity, *i.e.* only a few dominant paths exist in the channel estimation process, and from where the spatial-temporal domain information can be exploited in the estimation process. (Saloranta & Destino, 2016). To provide an effective solution utilizing a real hardware, we exploit the angular domain information only.

The beamforming algorithm is done in two phases depicted in Figure 1 and Figure 2. The first phase consists in

1. Dividing the 60deg aperture into 8 beams,
2. Selecting the max SNR beam and its neighbors,

The second phase consists in

1. Dividing the 3 previously selected beams in 8,
2. Selecting the maximum SNR beam.

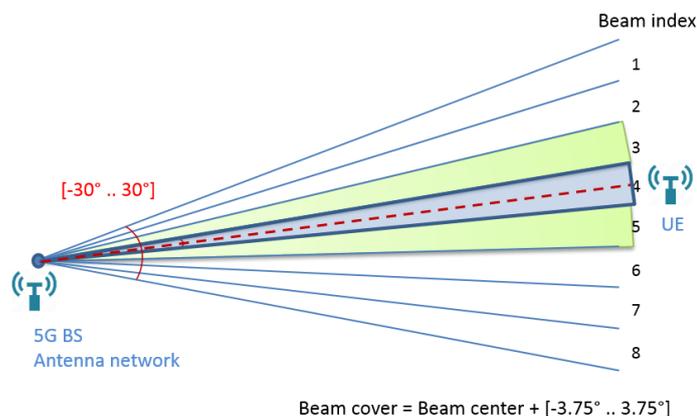


Figure 1: 1st phase of beam selection

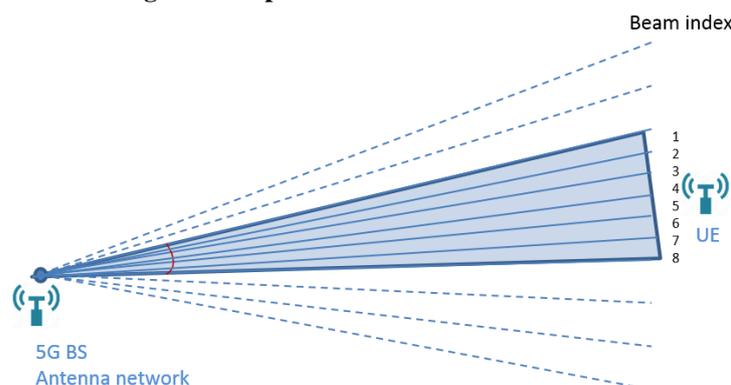


Figure 2: 2nd phase of beam selection

At the end of the beam selection process the obtained angular resolution of the selected beam is 2.8deg. As a consequence, the angular error model was chosen to be a uniform distribution as depicted in Figure 3.

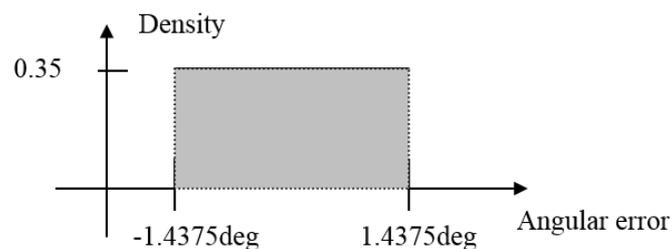


Figure 3: Angular error model

4.2 Single Positioning and Hybridization

5G observations are azimuth and elevation angles as defined in Figure 4.

¹ A radio frequency band of 30 – 300 GHz via exact definition. Although relaxed definition are e.g. from 23 – 32 GHz bands [P1].

5 RESULTS

5.1 Test Architecture

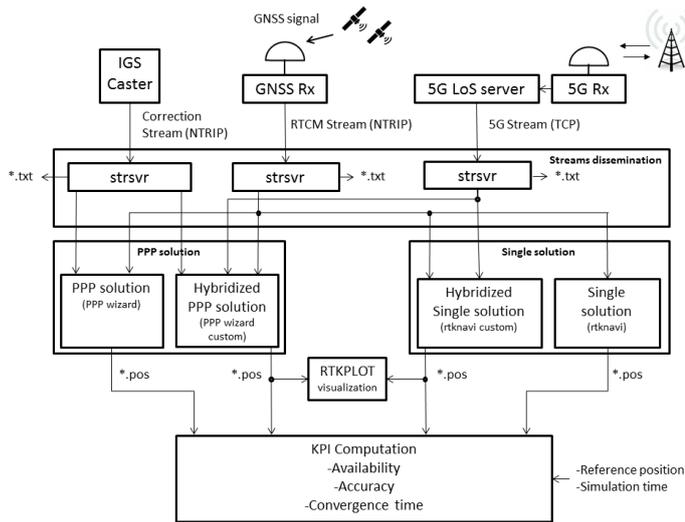


Figure 5: Test Bed architecture

The PPP corrections are retrieved from an IGS caster, and the GNSS observations are recorded from a mass market receiver (Samsung Galaxy S8 or ublox M8T). They are provided as RTCM streams through an NTRIP connection. 5G observations are provided through a TCP stream. To obtain results as close as possible to realistic beamforming antennas, only azimuth angles are included as 5G observation. The elevation angle is excluded and the hybridization algorithms receive one extra observation for each BS (instead of two observations).

The hybridization with Precise Point Positioning is computed with the customized software PPPwizard, while the hybridization with single point positioning (SPP) solution is computed with the customized rtknavi software from the open source suite RTKLIB.

Each solution is provided under the same file format and post-processed with a Matlab code.

5.2 KPI

The defined KPI are the availability, the accuracy and the convergence time (to obtain an accuracy better than 1 meter) of the solution.

5.3 Test Cases

The GNSS test environment are visibility conditions and are chosen to be clear-sky, urban and canyon environments. GPS, GLONASS and GALILEO constellations are used in the L1 band in order to be as close as possible to current mass market receivers.

The 5G conditions are the relative position of the 5G base stations (BS) with respect to the User Equipment (UE). The following BS locations are used:

- N20: North 20 meters (azimuth angle equals 180 deg from the 5G BS)
- N20 E20: North 20 meters and East 20 meters (two 5G BS: 180deg and 270deg)
- N20 SE20: North 20 meters and South-East 20 meters (two 5G BS: 180deg and 315deg)

Same locations were also tested using BS at 50m from the UE.

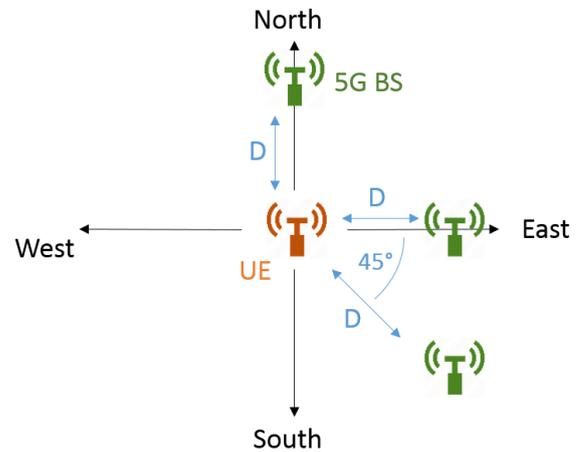


Figure 6: 5G BS locations with $D=20m$ & $D=50m$

5.4 Compared Performance

For computing the positioning accuracy a geo-referenced position was used for the open-sky environment and a precisely computed position for the urban and canyon environment.

5.4.1 Clear Sky

5.4.1.1 N50

The user is placed at 50 m from the 5G BS placed at North.

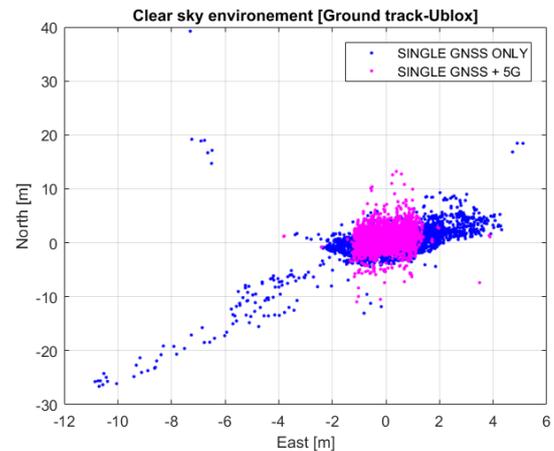


Figure 7: Ground track (SPP) with 1 BS at 50m North

The ground track visualization highlights the benefits of the extra observation for the perpendicular direction to the BS. In this case the dilution of the results became closer to the UE along the East-West direction. This observation is confirmed by the true error applied on this direction and provided on the figure hereafter.

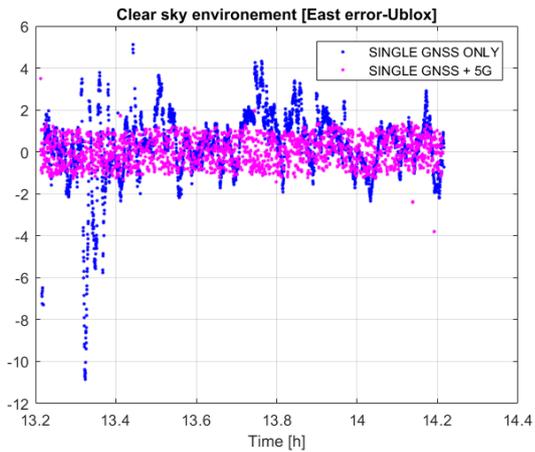


Figure 8: East errors (SPP) with 1 BS at 50m North
As expected from the ground track figure, the BS located at the North of the UE reduces the error on the East-West direction.

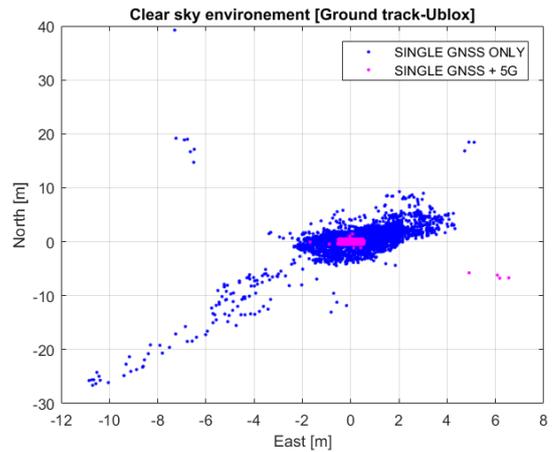


Figure 11: Ground track (SPP) with 2 BS at 20m North & 20m East

When 2 BS are visible from the UE, 2 extra observations are available. Using BS spaced from 90deg allows the UE to benefit from optimal combination of observations. The BS located at the North (resp. East) provides azimuth angle that narrows the solution on the East-West (resp. North-South) direction.

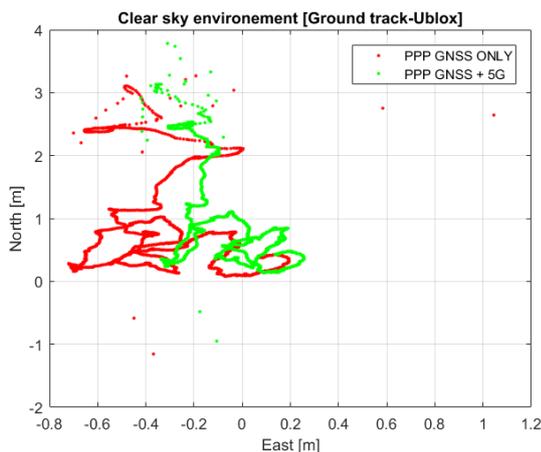


Figure 9: Ground track (PPP) with 1 BS at 50m North
The same behavior can be observed on the ground track of the PPP solution as for the SPP. Nevertheless the North error dilution (the major contribution of the error in this case) is not affected by the extra observation.

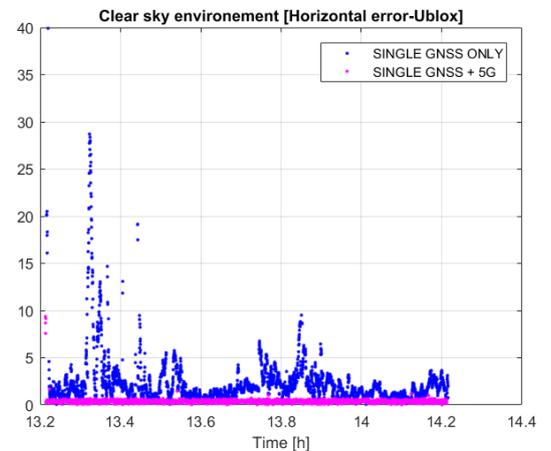


Figure 12: Horizontal errors (SPP) with 2 BS at 20m North & 20m East

Indeed the true horizontal error is greatly improved when using BSs 20m away from the UE.

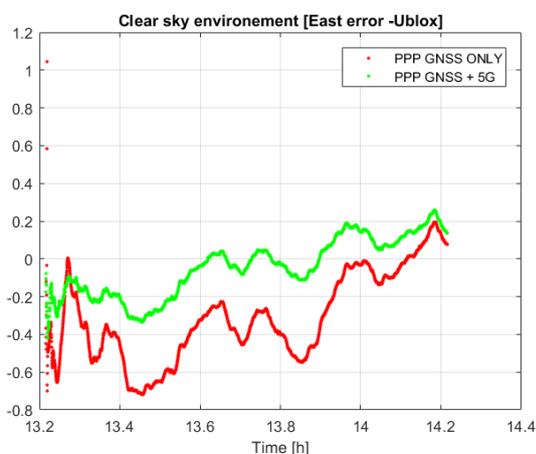


Figure 10: East errors (PPP) with 1 BS at 50m North
As foreseen from the ground track visualization, a slight improvement of the error can be observed on the East direction.

5.4.1.2 N20 E20

The user is placed at 20 m from two 5G BS located at East and North.

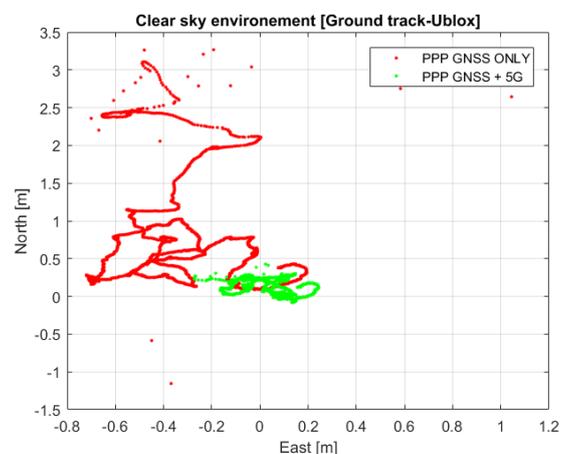


Figure 13: Ground track (PPP) with 2 BS at 20m North & 20m East

The same behavior as for the SPP can be observed on the ground track of the PPP solution resulting on an improved dilution on both North-South and East-West direction.

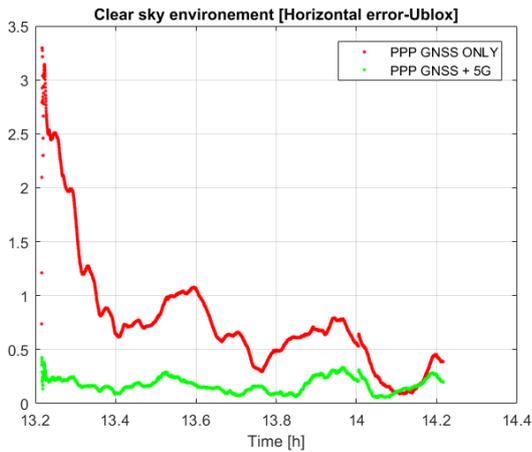


Figure 14: Horizontal errors (PPP) with 2 BS at 20m North & 20m East

As expected from the ground track figure, a great improvement of the horizontal error can be observed.

5.4.2 Urban

5.4.2.1 N20 SE20

The user is placed at 20 m from two 5G BS placed at South-East and North.

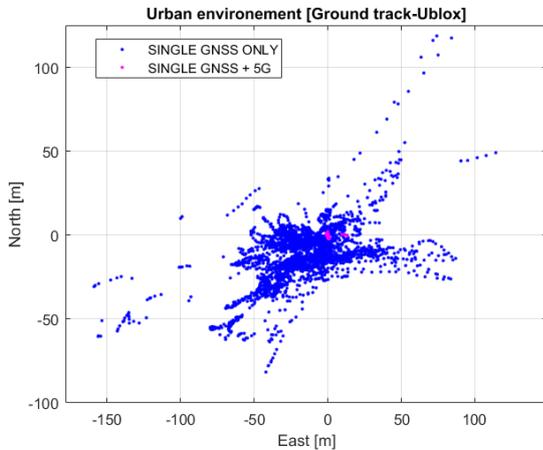


Figure 15: Ground track (SPP) with 2 BS at 20m North & 20m South-East

Under urban environment the dilution of the SPP horizontal error is degraded w.r.t. the open sky conditions. However the hybridized SPP dilution stays close to the UE even with low quality GNSS signals.

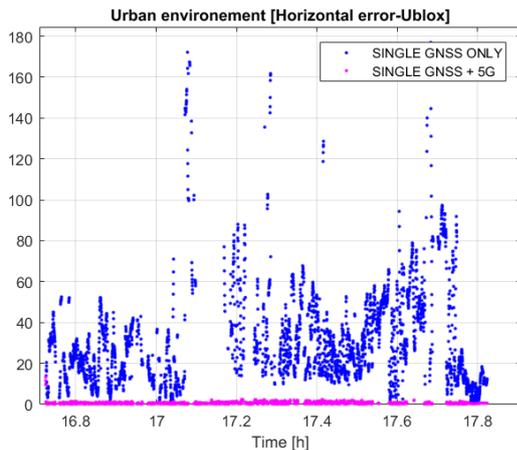


Figure 16: Horizontal errors (SPP) with 2 BS at 20m North & 20m South-East

As expected from the ground track figure, a great improvement of the horizontal error can be observed.

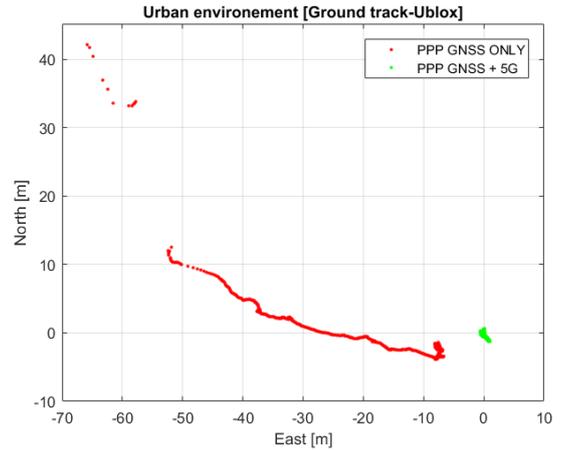


Figure 17: Ground track (PPP) with 2 BS at 20m North & 20m South-East

Under urban environment, the PPP solution does not provide sub-meter accuracy while the addition of 2 BS allows the precise positioning with sub-meter accuracy at 99th percentile.

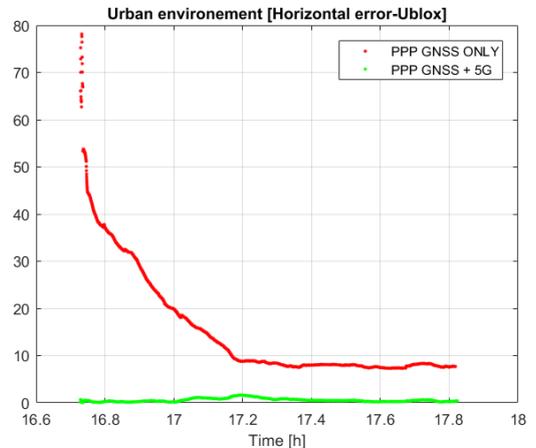


Figure 18: Horizontal errors (PPP) with 2 BS at 20m North & 20m South-East

The convergence process is greatly shortened by the use of 2 extra observations as the first fix is already close to the UE (under 5m).

5.5 Summary of the results

The results of this study are summarized in the Table 1. The canyon scenario was used to observe the limits of the solution proposed by reusing the input data from the urban scenario adding a satellite mask of 45° and using GPS only which leads to solutions with 3 satellites only.

Test Case	Conf.	Method	Availability [%]	Accuracy [m]					Convergence time [mn]
				Mean	Std	70th prctl	95th prctl	99th prctl	
Clear sky	No 5G	PPP	99.917	0.492	0.224	0.634	0.790	0.964	23.53
		Single	98.89	1.845	1.279	2.147	4.244	6.448	NA
	N50	PPP 5G	99.917	0.483	0.213	0.602	0.860	0.962	23.86
		Single 5G	99.972	1.635	1.165	1.873	4.063	5.754	NA
	N20 E20	PPP 5G	99.917	0.172	0.068	0.216	0.287	0.320	0
		Single 5G	99.74	0.381	0.150	0.467	0.595	0.663	NA
N20 SE20	PPP 5G	99.917	0.265	0.131	0.331	0.466	0.623	0	
	Single 5G	99.722	0.518	0.273	0.622	1.008	1.160	NA	
Urban	No 5G	PPP	91.722	15.174	11.509	16.068	37.975	53.170	No Conv.
		Single	72.645	41.789	101.768	40.389	84.826	175.059	NA
	N20	PPP 5G	91.722	2.012	2.070	2.269	3.002	4.023	No Conv.

N20 E20	Single_5G	77.645	14.504	30.005	14.872	31.662	114.191	NA	
	PPP_5G	91.722	0.492	0.202	0.597	0.836	0.923	28.217	
	Single_5G	72.396	0.430	0.198	0.516	0.745	0.918	NA	
	PPP_5G	91.764	0.479	0.208	0.572	0.858	0.949	31.8	
	Single_5G	72.757	0.725	0.448	0.904	1.608	1.901	NA	
	PPP_5G	91.764	0.479	0.208	0.572	0.858	0.949	31.8	
Canyon	NO 5G	PPP	0	No fix	No fix	No fix	No fix	NA	
		Single	0	No fix	No fix	No fix	No fix	NA	
	N20	PPP_5G	49.669	405.91	428.39	397.17	1402.5	1421.5	NA
		Single_5G	39.458	2256.062	14277.03 3	1310.511	4880.827	28832.35 3	NA
	N20 E20	PPP_5G	61.556	341.22	277.27	384.71	835.27	1277.5	NA
		Single_5G	66.105	0.4006	0.1848	0.4787	0.6449	0.7272	NA
	N20 SE20	PPP_5G	61.556	328.55	220.86	386.21	715.44	1020.60	NA
		Single_5G	66.157	0.517	0.280	0.605	1.029	1.197	NA

Table 1: Summary of results

For the canyon tests, only the solutions with 5G are possible. The test with a single 5G station shows extremely bad results. When checking the geometry of the solution, it appears that the 3 satellites used in the solution are aligned East-West. These leads to a geometric solution like a line North-South which is parallel to the plain equation provided by the 5G station. With such geometric conditions the user position is only observable on the East-West direction which leads to a bad positioning accuracy on the North-South direction.

6 CONCLUSIONS

The addition of a 5G antenna clearly improves the positioning accuracy in the direction perpendicular to the antenna by providing extra observations to the PVT algorithms. When the maturity of the beamforming antennas will allow the use of elevation angle the positioning accuracy is expected to be even better than the ones obtained during this project.

Sub-metric accuracy is achievable even in an urban environment with the use of two perpendicular 5G antennas 20m apart. Nevertheless the reader should know that the use of one BS in a perpendicular direction of a street under canyon environment could result in bad solution accuracy.

The outcome of these experimentations have shown the added value of the 5G when it comes to positioning performances (both for SPP and PPP). As observed in the last table, the 5G is especially important in the urban environments where GNSS signals are less available and the base stations are close enough. On the other hand, the interest of using 5G diminishes with the distance to the base station and one can imagine that in a rural environment, 5G positioning will not improve GNSS.

ACKNOWLEDGMENTS

The research leading to these results has received funding from the European Union H2020 5GPPP under grant n. 723247 and supported by the Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (No.B0115-16-0001, 5GCHAMPION).

REFERENCES

5GChampion. (2018). *Deliverable D6.3 - Integration and system testing phase of satellite scenario*.

International Technical Symposium on Navigation and Timing (ITSNT) 2018
13-16 Nov 2018
ENAC, Toulouse, France

(2018). *D6.3 Integration and system testing phase of satellite scenario*.

Kutty, S., & Sen, D. (2016). Beamforming for Millimeter Wave Communications: An Inclusive Survey. *IEEE Communications Surveys & Tutorials*, 18(2), 949-973.

Mueck, M., & et.al. (2016). 5G CHAMPION - Rolling out 5G in 2018. *Proc. IEEE Global Commun. Conf. Workshops*, (pp. 1-6).

Saloranta, J., & Destino, G. (2016). On the Utilization of MIMO-OFDM Channel Sparsity for Accurate Positioning. *24th European Signal Processing Conference (EUSIPCO)*, (pp. 748-752).

Saloranta, J., & Destino, G. (2017). Reconfiguration of 5G radio interface for positioning and communication. *25th European Signal Processing Conference (EUSIPCO)*.