

Geo Information Systems (incl. GPS/Galileo) state of the art and trends

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Introduction

Motivation

Objective

Agenda

Motivation

What is it for?

- Positioning, navigational and timing services.
- Most famous examples:
 - car navigation systems, trekking GPS receiver, electronic maps,
 - fee collecting system for highways,
 - military targeting, intelligent weapons,
 - etc.



Introduction

Motivation

Objective

Agenda

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 - car navigation systems, trekking GPS receiver, electronic maps,
 - fee collecting system for highways,
 - military targeting, intelligent weapons,
 - etc.

Why is it important?

- Significant capabilities in fields, like:
 - mapping, navigation, tracking, location services,
 - telecommunication, transportation applications,
 - mining & welling, research & development.
- American GPS recognized as the fifth utility, alongside water, electricity, gas and telephony.



Introduction

Motivation

Objective

Agenda

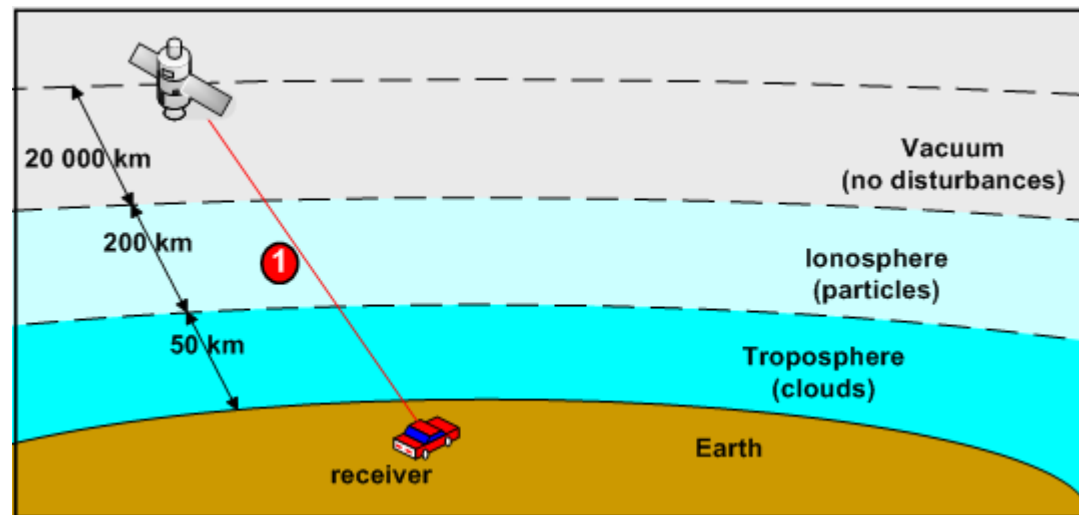
Objective

Augmentation

- Increase **precision**. Standard ~10m is not enough for most applications.

Why is it a problem?

- We assume, that the signal between satellite and receiver propagates in a homogeneous environment.





Introduction

Motivation

Objective

Agenda

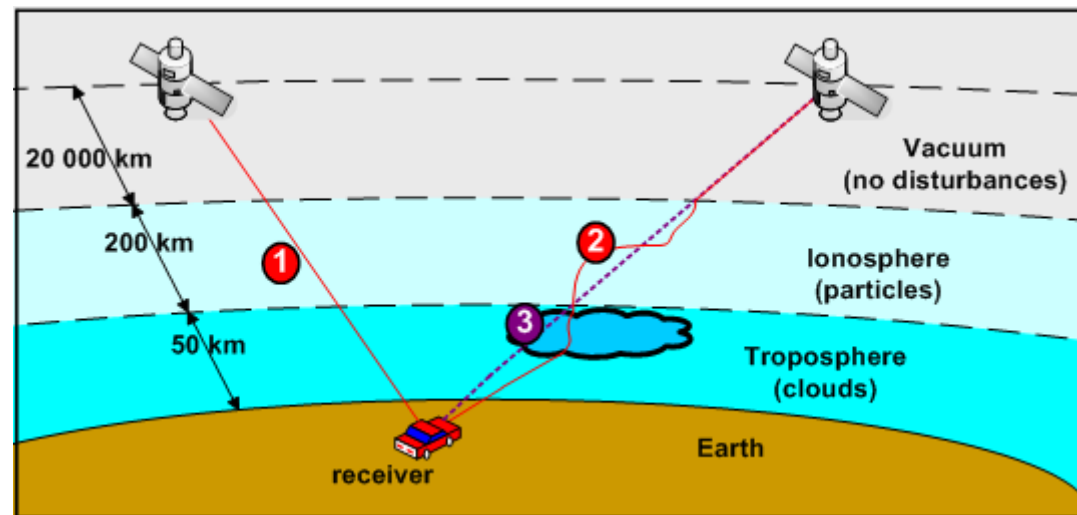
Objective

Augmentation

- Increase precision. Standard ~10m is not enough.

Why is it a problem?

- We assume, that the signal between satellite and receiver propagates in a homogeneous environment.
- But it is far from homogeneous...





Introduction

Motivation

Objective

Agenda

GNSS

Differential GNSS

Signal distribution

Summary

Agenda

Introduction

- overview of the problem – motivation & objectives

GNSS

- definition, way of working

Differential GNSS

- differential mechanism, problems

Signal distribution

- differential signal in public networks

Summary

- conclusions, outlook, other and future problems



Introduction

GNSS

Definition

Distance

Triangulation

Clock error

Differential GNSS

Signal distribution

Summary

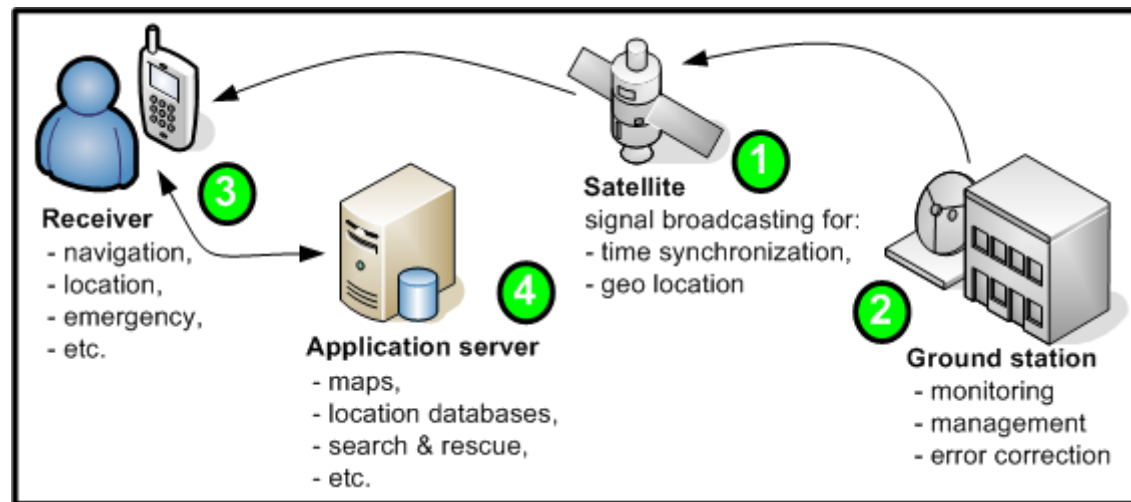
GNSS - Definition

Global Navigation Satellite System

- General name for positioning systems like GPS and Galileo

- Consists of:

- (1) satellites,
- (2) ground stations,
- (3) receivers,
- (4) application servers.



Simplified structure of GNSS



Introduction

GNSS

Definition

Distance

Triangulation

Clock error

Differential GNSS

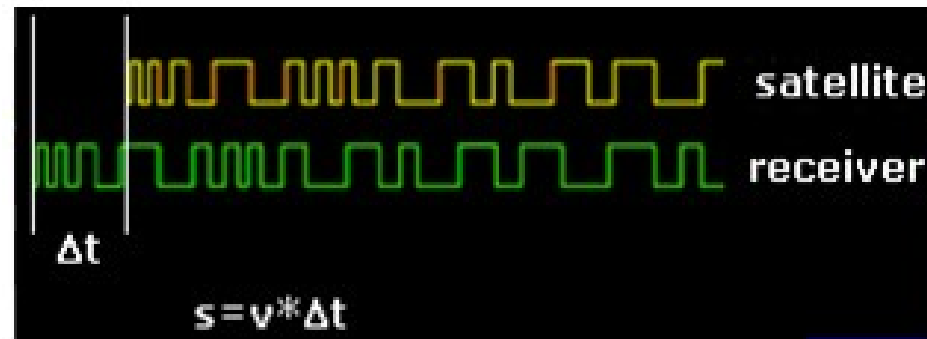
Signal distribution

Summary

GNSS - Working

Distance to a satellite

- satellite repeats a broadcast signal in equal intervals of time
- receiver starts the signal at the same moment
- time shift between the local signal and the received signal – propagation delay



Signals at the receiver



Introduction

GNSS

Definition

Distance

Triangulation

Clock error

Differential GNSS

Signal distribution

Summary

GNSS - Working

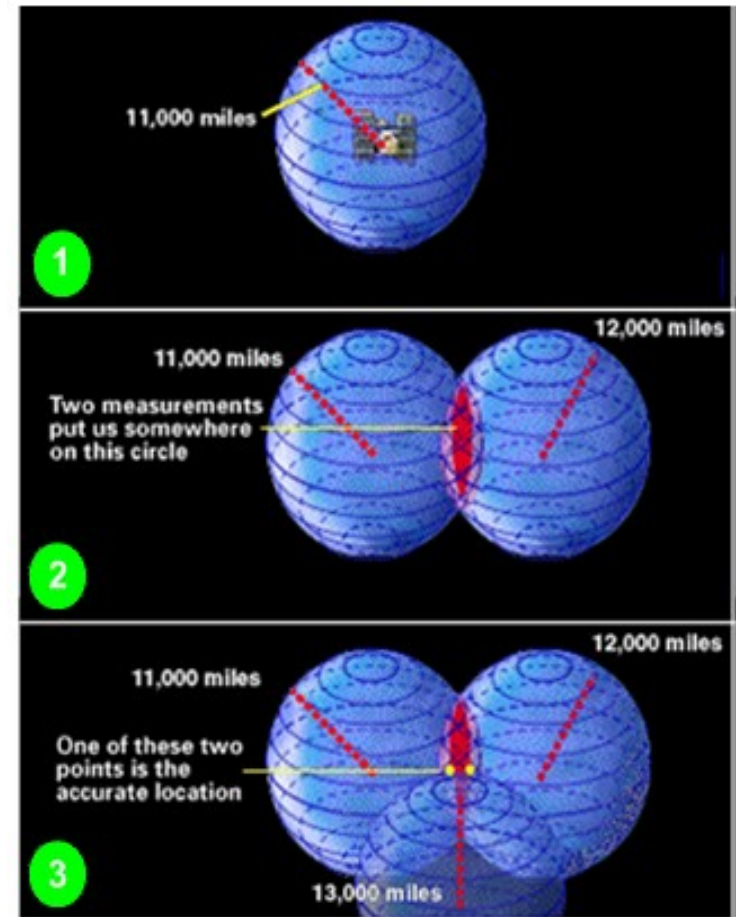
Triangulation from 3 satellites

(1) distance from one satellite – receiver somewhere at the surface of the sphere

(2) intersection of two spheres forms a circle

(3) intersection of three spheres – just two points

(4) one point may be simply eliminated – too far from the Earth, moving too quickly, etc.



3D triangulation process



Introduction

GNSS

Definition

Distance

Triangulation

Clock error

Differential GNSS

Signal distribution

Summary

GNSS - Working

Clock error elimination

- a mistake of 1 nanosecond causes 30cm location misplacement
- but an atomic clock costs 10-100 thousand dollars



Introduction

GNSS

Definition

Distance

Triangulation

Clock error

Differential GNSS

Signal distribution

Summary

GNSS - Working

Clock error elimination

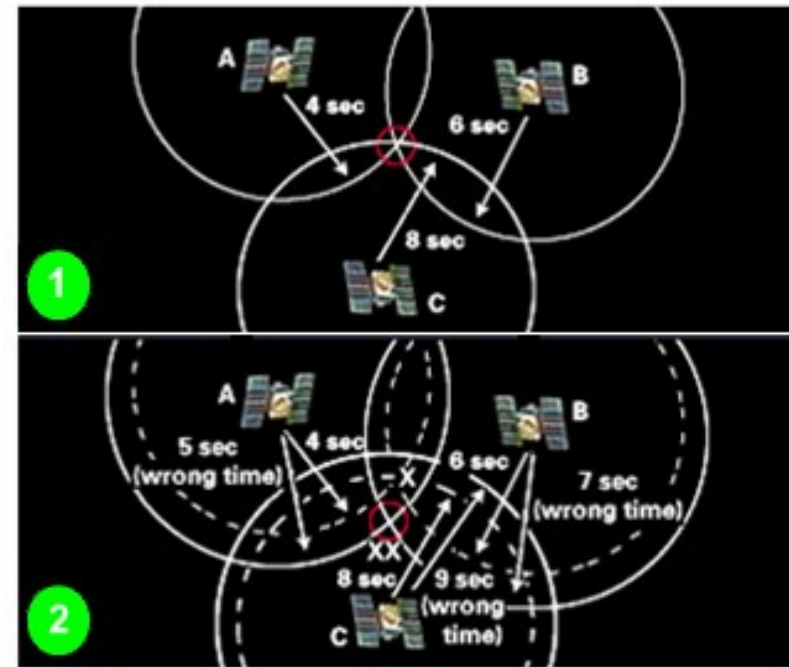
- a mistake of 1 nanosecond causes 30cm location misplacement
- but an atomic clock costs 10-100 thousand dollars

• other solution – add one more satellite:

(1) receiver has a perfect clock – all circles cross in the same point

(2) in reality – a geometrical mean will show the accurate location.

- 3rd satellite in 2D, means 4th satellite in 3D



Clock error on a 2D example



Introduction

GNSS

Differential GNSS

Errors

Architecture

Signal distribution

Summary

GNSS vs DGNSS

Potential system errors

- satellite clock drift, or orbit shift
- particles, clouds, water vapor, multi-path propagation
- receiver noise

<i>Error source</i>	<i>Standard GNSS</i>
Satellite clock drift	1,5 m
Orbit errors (ephemeris)	2,5 m
Ionosphere	5,0 m
Troposphere	0,5 m
Multi-path	0,6 m
Receiver noise	0,3 m
Total	~ 10,0 m

Satellite system error budget

GNSS error ~10m



Introduction

GNSS

Differential GNSS

Errors

Architecture

Signal distribution

Summary

GNSS vs DGNSS

Potential system errors

- satellite clock drift, or orbit shift
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- receiver noise

<i>Error source</i>	<i>Standard GNSS</i>	<i>DGNSS</i>
Satellite clock drift	1,5 m	0,0 m
Orbit errors (ephemeris)	2,5 m	0,0 m
Ionosphere	5,0 m	0,4 m
Troposphere	0,5 m	0,2 m
Multi-path	0,6 m	0,6 m
Receiver noise	0,3 m	0,3 m
Total	~ 10,0 m	~ 1,5 m

Satellite system error budget

GNSS error ~10m

DGNSS error ~1m



Introduction

GNSS

Differential
GNSS

Errors

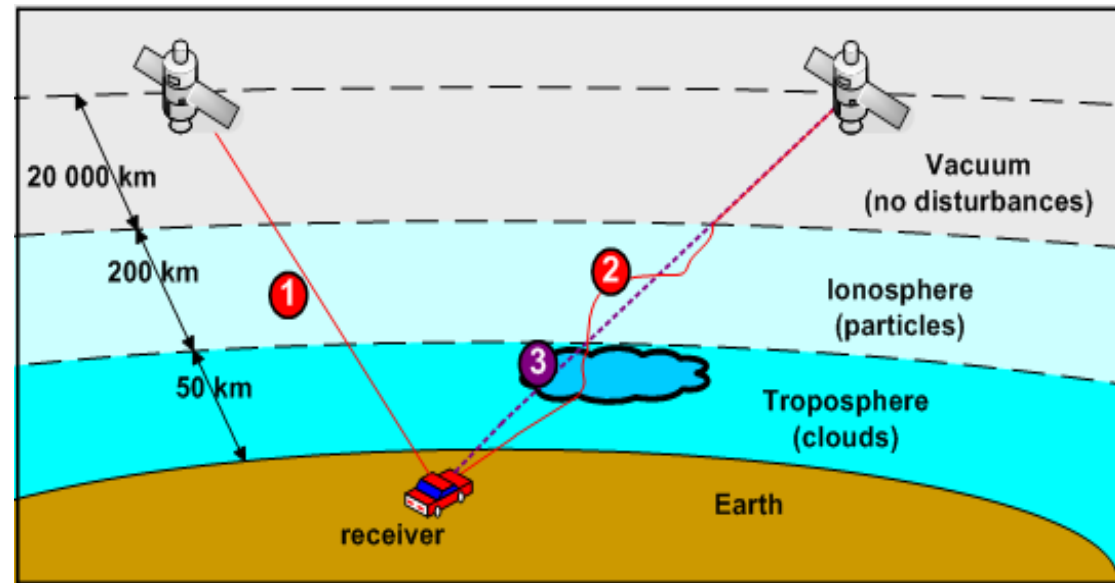
Architecture

Signal
distribution

Summary

DGNSS - Architecture

Non-Homogeneous environment problem



Weather conditions influence the signal



Introduction

GNSS

Differential
GNSS

Errors

Architecture

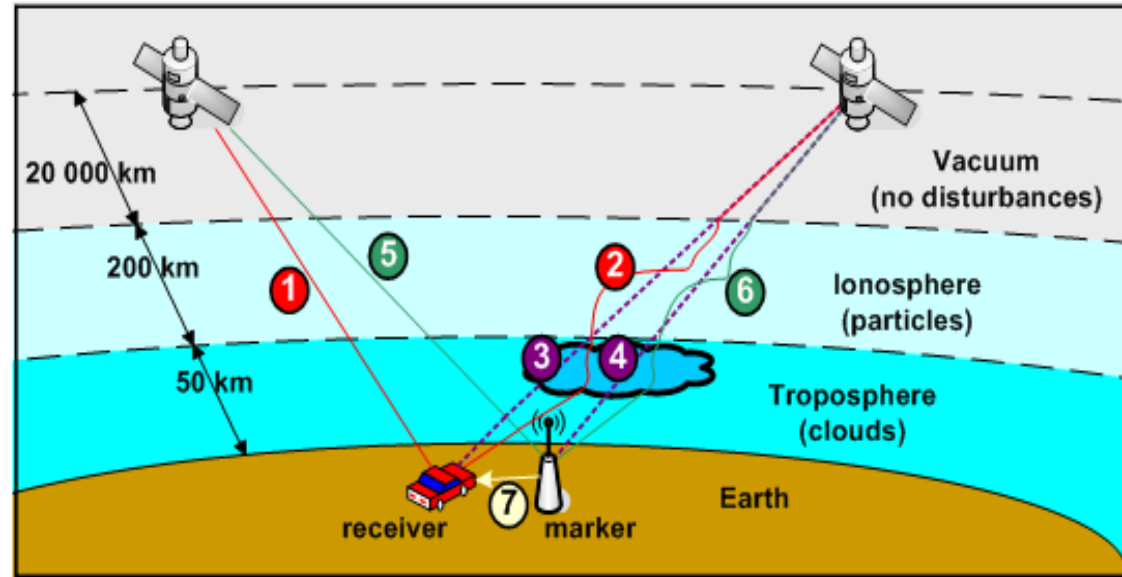
Signal
distribution

Summary

DGNSS - Architecture

Non-Homogeneous environment problem

- may be solved by adding some reference “markers”
- the proper delay between marker and satellite is known
- difference between the proper delay and the computed one shows system error
- knowing the system error, other receivers may eliminate it



DGNSS simplified architecture



Introduction

GNSS

Differential
GNSS

Signal
distribution

Problem

Solution

Summary

Problem in DGNSS

Distribution of the differential signal

- what platform to use?
- amount of available radio frequencies is limited,
- best solution – use already existing public network.



Introduction

GNSS

Differential
GNSS

Signal
distribution

Problem

Solution

Summary

Problem in DGNSS

Distribution of the differential signal

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- amount of available radio frequencies is limited,
- best solution – use already existing public network.

Internet

- most GNSS receivers embedded into mobile phones, PDAs, notebooks – devices already providing Internet connectivity
- Internet access networks are widely spread
- it would solve other problems and could be converged with other advanced IP services



Introduction

GNSS

Differential
GNSS

Signal
distribution

Problem

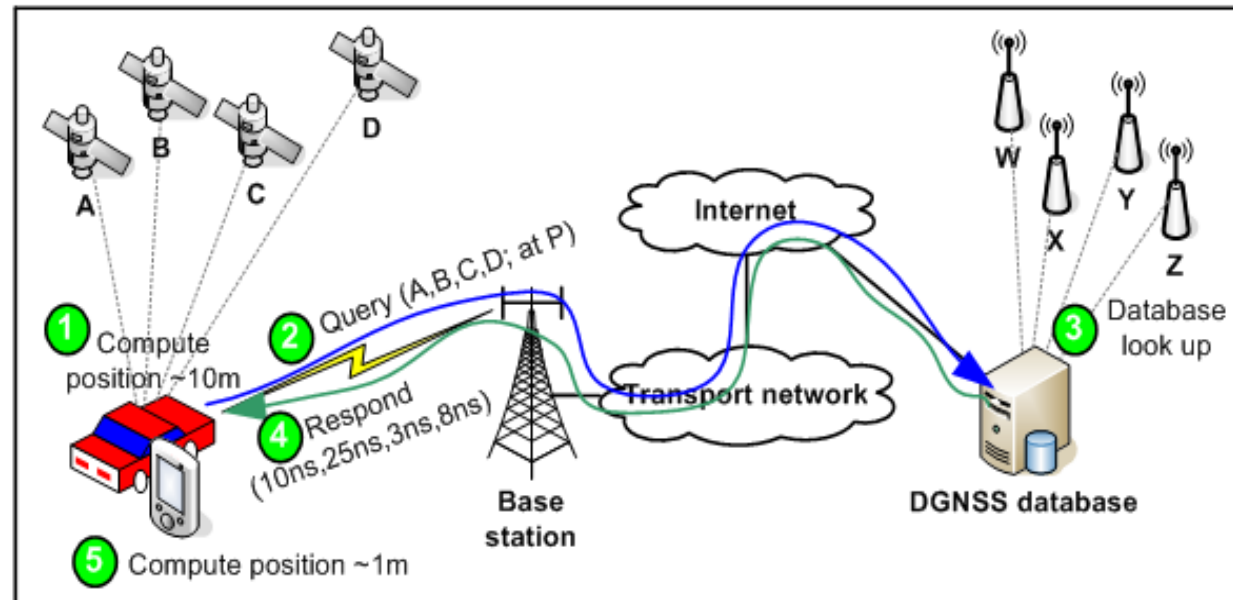
Solution

Summary

Problem in DGNSS

Differential signal distribution in IP network

- receiver send its approximate position to the database (1) together with the information about the used satellites (2)
- database lookup (3) returns the delay errors between the closest marker and the used satellites (4)
- exact position may be computed with a minimized error (5)



DGNSS differential signal distribution over IP network



Introduction

GNSS

Differential GNSS

Signal distribution

Summary

Conclusions

Outlook

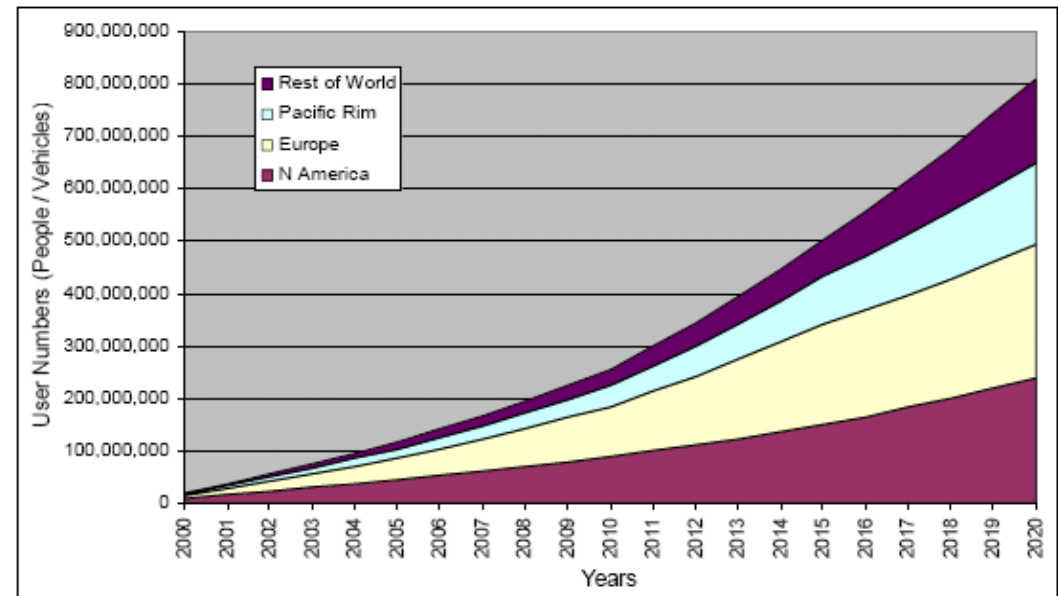
Conclusions

Increasing popularity of GNSS

Growing amount of GNSS applications and services

Accuracy of DGNSS should be sufficient

Incorporation of GNSS into IP world seems easiest and most promising solution



Market of GNSS receivers [by EU Commission]



Introduction

GNSS

Differential
GNSS

Signal
distribution

Summary

Conclusions

Outlook

Outlook

Spectrum of possible applications for GNSS

- Instant Messaging location based services,
- Intelligent Home location based applications,
- positioning by VoIP emergency calls.

Double edged sword problem

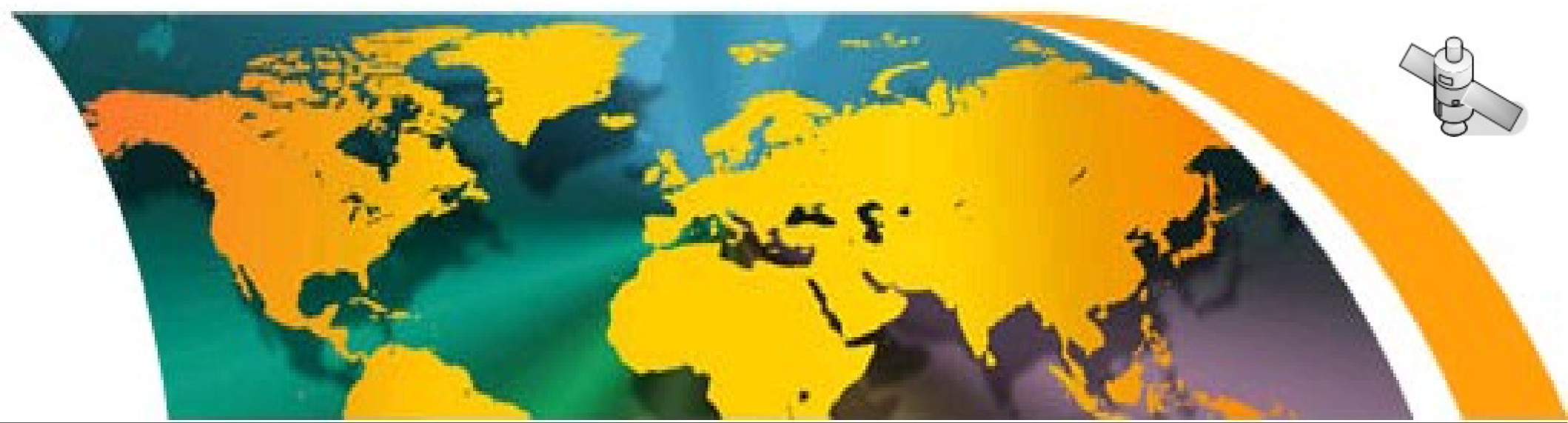
- on one hand – emergency positioning may increase our security,
- on the other – it may limit our privacy.

Distribution of differential signal over IP networks

- Ntrip standard introduced by Radio Technical Commission for Maritime Services (RTCM)
- applies to any kind of IP network and is already being tested

Cooperation vs Competition in GPS/Galileo/GLONASS

Military subjection of GPS and GLONASS



THANK YOU FOR YOUR ATTENTION!