Comparison of Different Proposals for Reference Station Network Information Distribution Formats

Hans-Jürgen Euler
Benedikt Zebhauser

Bryan Townsend
Forgis Technologies Inc., Canada

Gerhard Wübbena
Geo++ GmbH, Germany

September 2002

Published in Proceedings of ION GPS 2002
Portland, Oregon, September 24-27, 2002

Leica
Geosystems

Comparison of Different Proposals for Reference Station Network Information Distribution Formats

H.-J. Euler, B. E. Zebhauser, *Leica Geosystems AG, Switzerland*

B. R. Townsend*, Forgis Technologies Inc., Canada*

G. Wuebbena, *Geo++ GmbH, Germany*

ABSTRACT

Reference station networks have been already installed in several countries over the last years. The exchange in these installations is still based on proprietary information messages. The need for a standardized information exchange has been understood right from the early beginning. So far two different proposals have been discussed and are in discussion at RTCM for adoption and inclusion in the standard.

The first proposal has been drafted in 1999 by T. Melgård et al. A revised version was published by B. Townsend et al at ION GPS 2000. This proposal concentrates on keeping the message size small by transmitting only the minimum information required to correct the data from one reference station for the differential atmospheric and orbit errors experienced by the rover receiver.

The second proposal has been drafted during the ION GPS 2001 in Salt Lake City by Euler et al. While most proprietary information exchange within RTK networks is based on estimated and modeled biases, this proposal is based on differences of RTCM correction messages. Therefore only unmodelled information is being distributed. The impediment of detailed descriptions and negotiations of used modeling procedures is bypassed for reaching easier agreement on the standard document.

The paper will focus on the different proposals and weight their advantages and disadvantages. The paper's goal is a consolidated joint proposal for closing the discussions and speeding the adoption process for RTCM.

INTRODUCTION / MOTIVATION

Within the Subcommittee SC104 of RTCM a working group for the definition of network RTK was established some time ago. The working group's charter is the definition of a set of network RTK messages for interoperability by utilizing the RTCM V2.3 (or higher) or the new up-coming standard V3.0, which is still under discussion within the SC104.

In the mean time several proposals for messages are available for discussion. The first proposals were concentrating on providing a set of messages for RTCM V2.3, while newer proposals are concentrating exclusively on the RTCM V3.0. However, the V2.3 is well established for interoperability and a transition to a more compact V3.0 might not be feasible under all circumstances. Therefore this documents assume the validity of the up-coming definition for both versions, but may be more optimized towards V3.0. In the following the differences between the approaches will be discussed and rated against each other.
The consolidation of the discussions is required urgently for finalizing and releasing standard messages.

Euler et al. (2001) introduced the concept of correction differences to minimize the throughput for Network RTK messages. The paper outlines different ways of creating the information. The correction differences could be single differenced L1, L2, and the future also L5 phase observation corrections or, as outlined, also single differenced ionospheric and geometric corrections. RTCM66 (2002) also uses the ionospheric and geometric correction differences, even when the latter term is not used, for the distribution. The split into ionospheric and geometric correction differences may also provide an additional reduction in throughput (see Zebhauser et al. 2002 for more details). Since there is agreement in that choice, the paper concentrates on the ionospheric and geometry split types of correction differences only.

CRITERIA FOR COMPARISON

Several criteria might be important when comparing different proposals. One of the critical problems in RTCM data communication is the throughput. The data distribution is usually given and dependent on the broadcast medium being involved, therefore a very good compression rate for the distributed information will directly affect the refresh rate of the information itself. The information throughput for the distribution should be homogenous and have no larger peaks in order to avoid backlog in the flow of other important information sent through the same data link.

For interoperability it is very important to understand on the rover how the actual information was generated. Therefore a second important criterion is the completeness of the description on how the distributed information has to be generated.

A third criterion is the flexibility in the distribution concept. A network might be very large and cover a whole country or even a continent. From the algorithm point of view it is possible to handle all that information, but the feasibility for the distribution of the information is a different story. The accuracy of the network information should be homogenous over the whole network as long as the distribution of the reference stations providing the required observation data are equally distributed as well. Patches with different accuracy should be avoided.

REFERENCE STATION GRID CONCEPT

Townsend et al. (2000) are proposing the information distribution based on a grid model. The underlining grid is used for a compact way of defining the reference station coordinates for the particular part of information attached, e.g. tropospheric bias seen at a location. The network area is covered with a grid of a certain mesh width. Every grid point has a specific point number, which can be converted to the horizontal coordinates of that specific grid point as long as the grid origin's horizontal coordinates, and the stepwidth of the grid is known. Note that only the horizontal coordinate information for a reference station can be compressed very effectively, the height information for the reference stations is missing in the concept. All this information is collected in a Grid Definition message, which also holds the grid point IDs for the actual grid points being included in correction messages. The network grid might cover the world or only a small area.

The actual correction message is assembled of a message header (96 bits) and a block repeated per station (24 bits). The messages are designed to contain the information for one particular satellite and the correction, for example tropospheric, ionospheric, or orbit, for each reference station being defined in the grid. The original proposal contains no description how the correction content has to be derived. The content could be stipulated in the same manner as the content for the other approaches described later. This is assumed for the remainder of the paper and its analysis. Messages of the Grid concept will be abbreviated also with the prefix GD. GD25 denotes the Grid Definition message, while GD26 and GD27 denote the ionospheric and troposheric parts.

MASTER-AUXILIARY STATION CONCEPT

In Euler et al. (2001) and Zebhauser et al. (2002) the master-auxiliary station concept has been discussed in great detail. The basic idea is to reduce the original data content of the reference station observations as much as possible. The major variation of GNSS observation data can be very effectively reduced by building the so-called correction messages (type 20 and 21) as already standardized in RTCM V2.3 (2001). As a matter of fact only the satellite geometry changes are eliminated from the observation data. A further reduction of the range of variation might be achieved by between station single difference, because the remaining information will be affected only by the local and regional variations of ionosphere, troposhere, and orbit effects. In case the integer ambiguity numbers between the reference stations are available these numbers can be eliminated from the corrections as well. Under the assumption of correctly determined integer ambiguities within the whole network, the remaining variations describe the local and regional influences very precisely.

In this section some adaptations reflecting the most recent discussions in the RTCM SC104 committee will be summarized. The latter proposal (Zebhauser et al. 2002) shows flags allowing the use of different sections of the information to be included only at specific times. In the revised RTCM V3.0, as discussed and adopted during the May 2002 assembly of RTCM, flags for such purposes are excluded and therefore the proposals need to be adjusted. However, the restructuring for V3.0 might be taken over directly to the message structures for V2.3 (or higher) in order to avoid the definition of different message structures in both versions.

The comprehensive version RTCM14 (2002) shows in the appendix all details of proposed messages as described in Zebhauser et al. (2002). The message proposal allows extending its information content by the reference station coordinate differences for completeness of the available information. For the initial analysis in this paper the information has been completely separated and packed into different messages. For the sake of description the outcoming new messages are called MA25 (reference station coordinate differences given in horizontal and vertical components), MA26 (ionospheric contribution) and MA27 (tropospheric and orbit contribution). The acronym MA for Master-Auxiliary concept is used to avoid confusion with other concepts under discussion or with actually assigned RTCM message numbers. In the standard document proper message numbers have to be assigned. The definitions of the messages are shown in the appendix. The messages are given for reference station networks distributing information of GPS satellites only. For other networks providing information derived from other GNSS new messages with different message number, but the same possible content might have to be assigned.

The messages summarize all information for one reference station of the network. The original proposal assumes a network area of 300 km around a so-called master reference station with up to 16 auxiliary reference stations. However, the complete network size is not limited.

The initial proposal Euler et al. (2001) is based on the assumption that the messages will be used in conjunction with correction messages (types 20 & 21) exclusively. This allows reducing the information to be transmitted per satellite to be 8 bits less than in case where the network messages would be used in conjunction with raw observation messages (types 18 & 19), because the associated IODE for the broadcast ephemeris is required for proper use. The inclusion of IODE has been investigated in Zebhauser et al. (2002), but the inclusion was not outlined in great detail, because in the combination with correction messages (RTCM V2.3 types 20 & 21) these would supply the IODE information.

When all information has to be sent every epoch, the savings in throughput are significant, but will diminish with scheduling as it can be seen later in the paper.

The new concept for RTCM V3.0 does not allow sending the reference station coordinate information once in a while within the message. By any means one has different choices and always additional messages have to be created. The reference station coordinate information can be sent in an independent message or a separate message holding the reference station coordinate information plus correction differences. For the primary evaluation the completely separated messages have been used. The outline of the messages can be found in appendix, tables A-1 through A-4.

HIGH-LOW SATELLITE ELEVATION CONCEPT

RTCM66 (2002) builds on the Master-auxiliary concept and varies the proposals in some respect. First the defined network cell size permits up to 1000 km around the master reference station and the maximum number of auxiliary station was raised to 32. The idea of having the IODE included in the message and, therefore, the possibility of use in conjunction with raw observations (types 18 & 19) and correction messages (types 20 & 21) has been added.

As a main feature of the proposal the messages are defined to the transmission of so-called high-rate and low-rate satellite messages. Therefore the proposal is called High-Low concept with the abbreviation HL. High-rate satellite message would hold the information of satellites, which changes more rapidly than the information of other satellites. This should allow a better distribution of the throughput on the data-link. The message defining the coordinate differences between the master and the auxiliary reference stations is denoted by HL25, the ionospheric and the geometric correction differences are given with HL26 and HL27.

THROUGHPUT ANALYSIS

All three proposals have their merits for different applications. The main difference in view of the application between the Master-Auxiliary concept (MA) and the High-Low satellite concept (HL) is the size of a cell related to one master reference station for which correction differences are provided. The adaptation for identical areas covered are easy and manageable for both proposals, but should not be the focus of the analysis.

Table 2 summarizes the goals to be achieved for each concept used, which builds the basis for the analysis. The basic idea of the reference station grid concept is different to the others, but the message outline could be adapted for master-auxiliary reference approach as well. In order to allow the use of Grid concept with the same requirements as for the MA and HL concepts, the grid definition needs to be varied. The currently proposed resolution of the minimum step size has to be adjusted, which limits the overall area to cover to approximately 160 km, which is completely insufficient for today’s network RTK operation with correction differences.

	Grid concept (GD)	Master-Auxiliary (MA)	High-Low-rate (HL)
Station information	152 + 32 * N_{sta}	152	64 + 72 * N_{sta}
Ionospheric correction	96 + 24 * N_{sta}	88 + 24 * N^{sats}	72 + 24 * $N^{(sats)}$
Geometric correction	96 + 24 * N_{sta}	88 + 32 * N^{sats}	72 + 32 * $N^{(sats)}$

Table 1 Length of messages in bits

Table 1 gives the different message lengths in bits depending on:

N_{sta} number of reference stations
N^{sats} total number of satellites tracked
$N^{(sats)}$ number of satellites combined in one message (high-rate/low-rate satellites)

Area covered	1000 km around master reference station (80 km for grid concept)
Number of reference stations	15
Number of satellites tracked	6, 8, 10, 12
Horizontal coordinate resolution	2.5 m
Minimum update rate for ionospheric correction difference	2 sec
Minimum update rate for geometry correction difference	15 sec
Minimum update rate for complete reference station information (coordinates)	15 sec

Table 2 Minimum targets for transmission

Tables 3 and 4 show possible scheduling schemes for the Messages. For the Grid concept and the Master-Auxiliary concept the information of all auxiliary reference stations may be spread over several epochs allowing optimization of the throughput. The scheme for the High-Low-rate concept was already given in RTCM66 and has been taken from there. In the High-Low concept information from all auxiliary reference stations is sent at all epochs, but not the complete information of all satellites is included. The number of specific messages per epoch is indicated in brackets for all concepts. The abbreviations hr and lr are denoting the number of satellites designated as high rate and low rate satellites respectively. N^{sats} denotes the number of satellites tracked.

	GD	MA	HL
Station information	15 sec	Distributed over time	15 sec
Ionospheric correction	Distributed all information within 2 sec	Distributed all information within 2 sec	2 sec high rate
Geometric correction	Distributed 1 satellite for all stations per epoch	Distributed all information within 15 sec	12 sec

Table 3 General scheduling of messages

The last 2 digits of the message descriptor are indicating the content (25 for station or cell definition, 26 for ionospheric, and 27 for the geometric contribution). The leading 2 letters are indicating the concept used. The numbers in parenthesis are giving the number of specific messages per epoch (Number of satellites for GD and number of stations for MA).

Time [sec]	Grid concept	Master-Auxiliary	High-Low-rate
1	GD26(N^{sats}/2), GD27(1)	MA26(8), MA27(1), MA25(1)	HL26(hr)
2	GD26(N^{sats}/2), GD27(1)	MA26(7), MA27(2), MA25(1)	HL26(lr)
3	GD26(N^{sats}/2), GD27(1)	MA26(8), MA27(1), MA25(1)	HL26(hr)
4	GD26(N^{sats}/2), GD27(1)	MA26(7), MA27(2), MA25(1)	HL27(hr)
5	GD26(N^{sats}/2), GD27(1)	MA26(8), MA27(1), MA25(1)	HL26(hr)
6	GD26(N^{sats}/2), GD27(1)	MA26(7), MA27(2), MA25(1)	HL26(lr)
7	GD26(N^{sats}/2), GD27(1)	MA26(8), MA27(1), MA25(1)	HL26(hr)
8	GD26(N^{sats}/2), GD27(1)	MA26(7), MA27(2), MA25(1)	HL25
9	GD26(N^{sats}/2), GD27(1)	MA26(8), MA27(1), MA25(1)	HL26(hr)

10	GD26(N^{sats}/2), GD27(1)	MA26(7), MA27(2), MA25(1)	HL26(lr)
11	GD26(N^{sats}/2), GD27(1)	MA26(8), MA27(1), MA25(1)	HL26(hr)
12	GD26(N^{sats}/2), GD27(1)	MA26(7), MA27(2), MA25(1)	HL27(lr)
13	GD26(N^{sats}/2), GD27(1)	MA26(8), MA27(1), MA25(1)	HL26(hr)
14	GD26(N^{sats}/2), GD27(1)	MA26(7), MA27(2), MA25(1)	HL26(lr)
15	GD26(N^{sats}/2), GD27(1), GD25	MA26(8), MA27(1), MA25(1)	HL26(hr)

Table 4 Scheduling of messages

For the master-auxiliary and the high-low rate concepts the information will be sent station-wise, while the grid concept is satellite-oriented. Therefore the total information can be spread over time and the throughput will be more or less regularly distributed. In the grid concept the bulky grid definition message has to be sent once in a while, which dilutes a regular throughput.

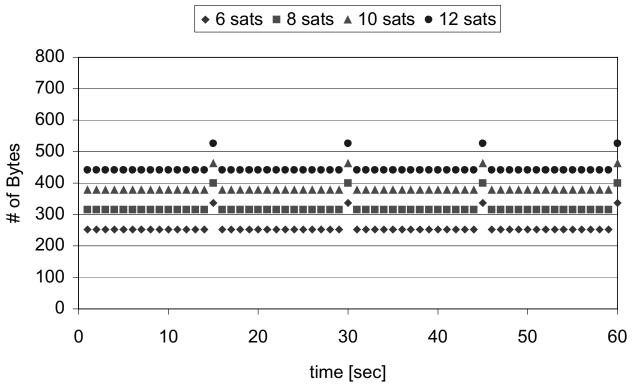

Figure 1 Throughput of Grid concept

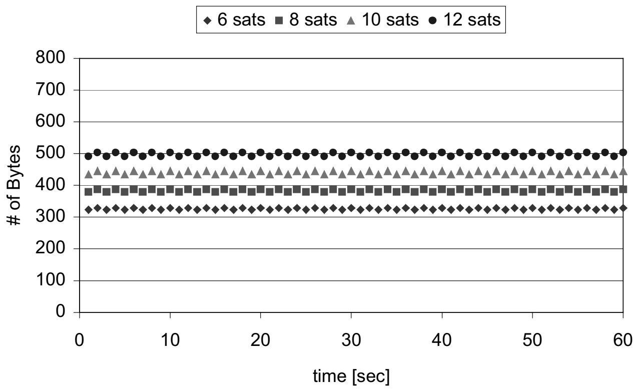

Figure 2 Throughput of Master-Auxiliary concept

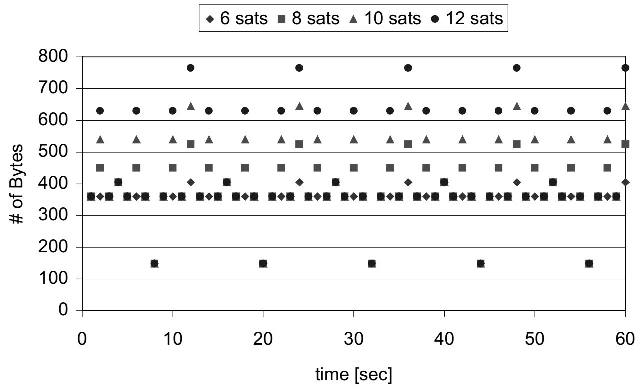

Figure 3 Throughput for High-Low rate concept

Figures 1-3 picture the throughput of the three concepts. While the High-Low rate concept shows some significant peaks in the throughput the Grid and Master-Auxiliary concepts provide a more homogenous distribution. Note that in the HL concept the ionospheric correction is only updated every 2 seconds for high-rate satellites while low-rate satellites are only updated every 4 seconds. GD and MA are updating the ionospheric correction difference for all satellites within 2 seconds.

The network definition is updated at one particular epoch for the HL and GD concepts (every 12 and 15 seconds, respectively). For MA the time when the complete transmission of all station information is concluded depends on the number of auxiliary reference stations. In the particular given schedule with 15 stations, it takes 15 seconds. However the scheduling could be changed and always 2 MA25 messages could be sent. The whole information would then be transmitted within 7-8 seconds for the example chosen. It should be noted that the time needed for transmission is crucial under the assumption that the calculations can be started only when the whole set of information, correction differences for all auxiliary reference stations, is available on the rover. This time represents the amount of time needed to initialize the system with the network information after system startup or getting online. However today's GPS RTK equipment also needs time to start tracking and collect the ephemeris for the processing. The cold start times are considerably longer than the overall time of 15 seconds needed for the initialization of the network information.

The throughput analysis with different number of auxiliary reference stations (e.g. 6 and 10) shows similar behavior.

TIME REFERENCE AND CLOCK OFFSET

The MA could allow one always to send the most actual information for all auxiliary reference stations, since the corrections are sent station-wise. For other messages the referenced time tag for the geometric correction may be changed only after the full set of information has been transmitted, since receiver clock offsets have to be identical for all satellites per station. The ionospheric correction can be considered less sensitive, since, under the assumption of identical clock offsets for all L1 and L2 observations, it is completely eliminated. However, in case where a GPS receiver has separate clocks for L1 and L2 or analog parts of the receiver antenna combination may influence the clock difference between L1 and L2 over time, one has to observe that fact. The conclusion is that the HL concept cannot be extended to the geometric correction and it could be dangerous also for the ionospheric correction, when there is a remaining variable clock offset in the ionospheric correction.

One of the original ideas by designing the MA concept was also the possibility of reconstructing the original observations at the auxiliary reference station. This might be required when handing over to the next master reference station. Therefore, it is mandatory to send also correction differences for geometry and ionosphere with identical time tags.

RESOLUTION AND RANGE OF MESSAGES

In the MA concept the resolution has been chosen to allow the reconstruction of original observation without significant loss of accuracy. The proposed resolution is 0.5 mm, which is the same as for observation messages. The range of the correction differences in the MA concept is sufficient for an area of 300km radius around the master reference station.

The HL concept introduces lower and different resolutions in order to make it adjustable for larger distances up to around the master reference station. The variation for ionospheric correction is 1 and 10 mm and for the geometry 1 and 3 mm. One has to observe that the lesser resolution will increase artificially noise when reconstructing original observations. The same problem arises when the actual location for positioning in the field is close to an auxiliary reference station, whose information has been distributed with less resolution. An artificial noise will be introduced to the observations, especially for low elevation satellites.

FIXED AND FLOAT AMBIGUITIES

In Zebhauser et al. (2002) a flag to indicate the status of integer ambiguity resolution has been introduced, which has been adopted for RTCM66 (2002) as well. When all integer ambiguities among the network have been successfully resolved, the corrections for ionosphere and geometry can be calculated without any hypothesis. The values will be affected only by the observation errors such as noise and, of course, multipath effects. This makes the calculation of the corrections quite easy and standardizable and it is also the feature which allows generation of "original" observations of auxiliary reference station out of the master reference station and the correction differences.

Correction differences based on float ambiguities are another story. To be strict the calculation has to be standardized for complete interoperability.

INTEGER AMBIGUITY ISSUE NUMBER

RTCM66 (2002) introduces the so-called integer ambiguity issue number. The number should indicate the integer ambiguity set used in the determination of the correction differences. In principle this is a smart idea, since the ambiguity issue number should show when an interpolation between successive values of either the ionospheric or geometric correction differences is possible without problems as long as this number is not changing.

Unfortunately, it bears some difficulties in usage. Whenever an integer ambiguity number as basis for the calculations of correction differences is changing, the number should be incremented. However, there is a question open, when a new satellite is included into the calculation of correction differences, should the number be increased even though the number of the remainder of the whole stable constellation did not change at all? With satellites observed very close to the horizon today's GPS receiver suffer sometimes from a lot of cycle slips, since the satellite's signals are very weak and they might be influenced by heavy multipath, diffraction or ionospheric disturbances. Every of these cycle slips would cause an increase of the integer ambiguity issue number.

Therefore a changing integer ambiguity issue number could indicate the total change of the whole integer ambiguity set or just the change in an ambiguity of a low satellite which might be of minor interest at the location where the information has been received. The impact on the calculations at the user station based on the received information need to be substantially different. More discussions are required until the integer ambiguity issue number will get a thoroughly defined meaning.

LOSS OF MESSAGES

The whole design of RTCM standard is based on the assumption that the information is distributed in a broadcast mode. Messages might be lost or not received by the user equipment. This means for the MA and HL concepts that the update of information for a complete station or part of it is missing. The GD concept favors the bundling of information by satellite. The loss of a message would mean that a satellite is missing. With only few satellites available, let us assume 5, that will cause certainly problems for operation in the whole cell, because only 4 satellites will remain for positioning. The roving equipment would be incapable for proper initialization until the next complete set of messages will be received. The same applies if the message for a constellation-critical satellite will be lost in the transmission. For a problematic reception area the loss of messages might be frequent and the roving equipment could end up with no usable network information for operation. Substituting the most recent information by using the information of previous epochs may mitigate this critical situation, but is not preferable, since for all satellites information has to be used from previous epochs consistently. The geometry correction difference changes very slowly and it is not so critical to have the newest information but that does not help during system start up. However the GD concept does not need as much throughput as the other concepts.

For the MA and HL concepts, if the information for a particular station is missing, this may create a problem in a limited area, but not the whole cell. There is also the chance that the information of other auxiliary stations will mitigate the problem and precise positioning is possible in the whole cell. The repeated loss of information will also not be disastrous, since information of different epochs can be mixed without difficulties as long as the variation of the information does not change drastically and the used information of a particular station is not too old.

FURTHER IMPROVEMENTS

The designs of the different concepts in the comparison separate the information by the content. The proposal described in Euler et al. (2001) allowed the combination of different information in one message. As described earlier the presence of flags announcing a particular set of information violates the new design concept for RTCM V3.0, where flags should not be used to indicate the extension of the message with another block of information. The analysis in the first part of the paper is based on totally separate messages, but following the new concept additional messages have to be drafted. Since each additional message sent per epoch adds overhead from the message framing and duplicated information into the data stream, the introduction of combination messages makes sense.

In principle all possible combinations of message content could be combined, but a closer investigation of the schemes shown above makes it obvious that only few are required. The information of the ionospheric correction difference has to be sent with the highest frequency. So, it makes most sense to combine this information with the other information content being sent less frequently. The coordinate difference information of the auxiliary reference stations was already mentioned above, but also the geometrical part can be combined with the ionospheric correction. In the appendix two additional messages (MA28 and MA29, tables A-5 and A-6) have been included, which reduce the load on the data link. In MA28 the message has a modified block repeated for each satellite and holds both the geometric and the ionospheric correction differences. The header section for MA29 holds the coordinate differences between the master and auxiliary reference stations and is therefore different to the header version used for MA26, MA27 and MA28.

Time [sec]	Grid concept	Master-Auxiliary	High-Low-rate
1	GD26(N^{sats}/2), GD27(1)	MA26(6), MA28(1), MA29(1)	HL26(hr)
2	GD26(N^{sats}/2), GD27(1)	MA26(4), MA28(2), MA29(1)	HL26(lr)
3	…	…	…

Table 5 Scheduling for improved MA concept

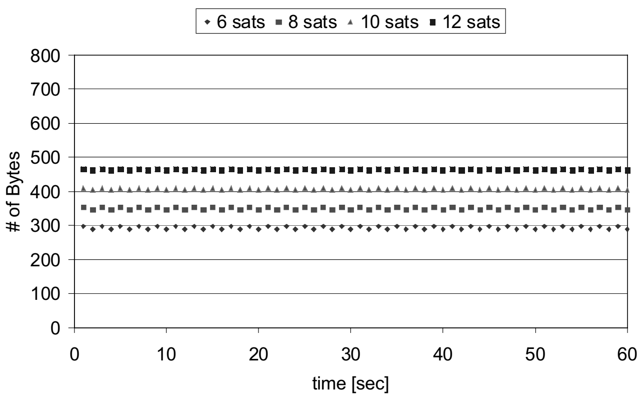

Figure 4 Improved Master-Auxiliary messages

Figure 4 shows the number of bytes to be transmitted with this improved Master-Auxiliary concept. The messages have been scheduled to allow the transmission of the identical data content for 15 auxiliary stations as given in table 4, but the messages MA 29 and MA28 substituted for MA25 and MA27, respectively. The scheduling for the improved MA concept is given in table 5 for the first 2 epochs.

CONCLUSIONS

The Grid concept would need to be updated. The network definition message lacks a significant information. However it was never meant for use with correction differences. An adaptation for more accurate coordinate representation allowing the coverage of a larger area and also the inclusion of the height value is required. A critical aspect is the impact of lost messages, but the messages are very compact.

The MA and to some extent the HL concept are less affected by the loss of some messages. In respect of throughput, the HL concept does not provide gain, because of the inhomogeneous byte load over time. The MA concept needs more bytes on average, but the utilization of the transmission media does not show the peaks as with the HL concept. Each of the concepts shows potential for improvement. The MA concept can be improved by combining some of the information as shown previously. This will increase the throughput performance. It has to be stressed again that the Master-Auxiliary concept has a higher overall load on the data link, since the ionospheric contribution of the correction differences is updated for all satellites every 2 seconds. This is in contrast to the approach in the High-Low concept where only high rate satellites are updated every 2 seconds and the low rate satellites are updated every 4 seconds.

The integer ambiguity issue number has been adopted from RTCM66 (2002) as it was described there. However, the potential use has been discussed, but no comprehensive utilization can be envisioned as it stands at the moment. The issue needs to be addressed during the next RTCM meeting.

The basis of the High-Low rate concept and the Master-Auxiliary concept is almost identical, but the Master-Auxiliary concept shows advantages in flexibility, homogenous throughput, and frequency of transmission for potential critical information such as the ionospheric correction differences. Therefore the Master-Auxiliary concept should be preferred for future network RTK messages.

REFERENCES

Euler, H.-J., Keenan, C.R., Zebhauser, B. E., Wübbena, G. (2001): Study of a Simplified Approach in Utilizing Information from Permanent Reference Station Arrays, ION GPS 2001, September 11-14, 2001, Salt Lake City, UT

RTCM14 (2002): A Novel Approach for the Use of Information from Reference Station Networks Conforming to RTCM V2.3 and Future V3.0, RTCM paper 014-2002-SC104-268 - NW MESSAGE PROPOSAL

RTCM66 (2002): Network RTK Format Proposal for RTCM-SC104 Version 3.0 by Trimble Navigation, RTCM paper 066-2002-SC104-281- TRIMBLE NETWORK RTK FORMAT PROPOSAL

Townsend, B., VanDierendonck, K., Neumann, J., Petrovski, I., Kawaguchi, S., Torimoto, H. (2000): A Proposal for Standardized Network RTK Messages, ION GPS 2000, 19-22 September 2000, Salt Lake City, UT

Zebhauser, B. E., Euler, H.-J., Keenan, C.R., Wübbena, G. (2002): A Novel Approach for the Use of Information from Reference Station Networks Conforming to RTCM V2.3 and Future V3.0, ION NTM 2002, January 28-30, 2002, San Diego, CA

APPENDIX 1: CONTENTS OF THE MESSAGES

Parameter	# bits	Resolu-tion	Unit	Range
Message Number	12	1	None	"MA25"
Number of Auxiliary Stations Transmitted	4	1	None	0 to 15
Network ID	5	--	None	0 to 31
Master Ref. Station ID	12	1	None	0 to 4095
Auxiliary Station ID	12	1		0 to 4095
WGS84 dLat	18	25	10^{-6} °	±3.2767 degrees
WGS84 dLon	19	25	10^{-6} °	±6.5535 degrees
WGS84 dHgt	22	1	Mm	±2097.151 m
$\sum$ =	104			13 Bytes

Table A-1 Message MA25 for coordinate differences between master and auxiliary reference stations

Parameter	# bits	Resolution	Unit	Range
Message Number	12	1	None	"MA26", "MA27", or "MA28"
Epoch Time (TOW/TOD)	23	0.1	Sec	0 to 603,799.9 sec
M = Multiple Message Indicator	1	--		
Integer Ambiguity Issue Number	8	--	None	0 to 255
Auxiliary Station ID	12	1		0 to 4095
Network ID	5	--	None	0 to 31
Reserved (ambiguity issue number)	4	1	None	0 to 15
# of GPS Sats	7	--	None	1 to 32
∑ =	72			9 Bytes

Table A-2 Message header for MA26, MA27 and MA28

Parameter	# bits	Resolution	Unit	Range
Satellite ID	6	1	None	1 to 32
Ambiguity Fixed/Float Flag	1	-	None	0 = Fixed 1 = Float
Ionospheric Carrier Phase Correction Difference	17	0. 5	mm	±32 meters
∑ =	24			3 Bytes

Table A-3 Repeated per satellite in messages "MA26" and "MA29"

Parameter	# bits	Resolution	Unit	Range
Satellite ID	6	1	None	1 to 32
Ambiguity Fixed/Float Flag	1	-	None	0 = Fixed 1 = Float
Geometric Carrier Phase Correction Difference	17	0. 5	mm	±32 meters
IODE	8	1	None	
∑ =	32			4 Bytes

Table A-4 Repeated per satellite in message "MA27"

Parameter	# bits	Resolution	Unit	Range
Satellite ID	6	1	None	1 to 32
Ambiguity Fixed/Float Flag	1	-	None	0 = Fixed 1 = Float
Geometric Carrier Phase Correction Difference	17	0. 5	mm	±32 meters
IODE	8	1	None	
Reserved	7	-	----	0
Ionospheric Carrier Phase Correction Difference	17	0. 5	mm	±32 meters
∑ =	56			7 Bytes

Table A-5 Repeated per satellite in message "MA28"

Parameter	# bits	Resolution	Unit	Range
Message Number	12	1	None	"MA25"
Number of Auxiliary Stations Transmitted	4	1	None	0 to 15
Integer Ambiguity Issue Number	8	--	None	0 to 255
Network ID	5	--	None	0 to 31
Master Ref. Station ID	12	1	None	0 to 4095
Auxiliary Station ID	12	1		0 to 4095
WGS84 dLat	18	25	10^{-6} °	±3.2767 degrees
WGS84 dLon	19	25	10^{-6} °	±6.5535 degrees
WGS84 dHgt	22	1	Mm	±2097.151 m
Epoch Time (TOW/TOD)	23	0.1	Sec	0 to 603,799.9 sec
M = Multiple Message Indicator	1	--		
Reserved	1	-	---	0
# of GPS Sats	7	--	None	1 to 32
∑ =	144			18 Bytes

Table A-6 Message MA29 header with auxiliary reference station coordinate differences

APPENDIX 2: ASSEMBLY OF THE MESSAGES

The messages MA25 through MA29 are assembled for the Master-Auxiliary concept with the defined blocks of information content tables A – 1 through A – 6 as shown in the following:

Message MA25 Auxiliary reference station definition

(A–1) 13 Bytes

Message MA26 Ionospheric correction difference

(A–2) 9 Bytes	1st (A–3) +	2nd (A–3) n times	…	nth (A-3) 3 Bytes

Message MA27 Geometric correction difference

(A–2) 9 Bytes	1st (A–4) +	2nd (A–4) n times	…	nth (A-4) 3 Bytes

Message MA28 Combined ionospheric and geometric correction difference

(A–2) 9 Bytes	1st (A–5) +	2nd (A–5) n times	…	nth (A-5) 7 Bytes

Message MA29 Auxiliary reference station coordinate differences plus ionospheric correction differences

(A–6) 18 Bytes	1st (A–3) +	2nd (A–3) n times	…	Nth (A-3) 3 Bytes

In the first line the blocks are indicated. The second line provides information on the number of Bytes being added with the blocks. Note that each message will also contain a number of header bytes, 2 or 3 bytes depending on the length of the messages content, and the 3 bytes for the cyclic redundancy check (CRC). These 5 to 6 bytes build up an overhead which can be mitigated by lumping information together as done for messages MA28 and MA29.

733728en – XI.02 – RVA

Leica Geosystems AG
CH-9435 Heerbrugg
(Switzerland)
Phone +41 71 727 31 31
Fax +41 71 727 46 73
www.leica-geosystems.com