Government of **Western Australia**
Department of **Water**

IP Telemetry Trial Notes

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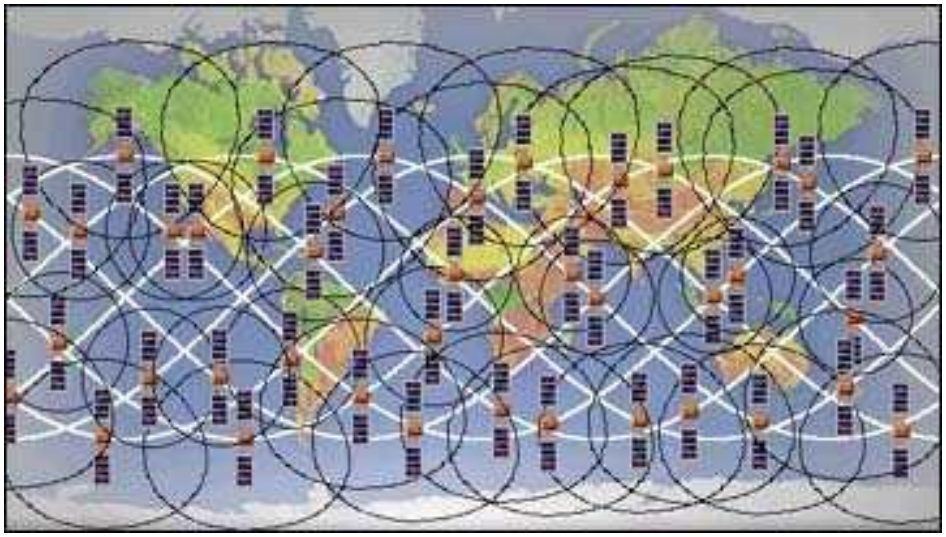
INTRODUCTION

The following describes some issues and outcomes about IP telemetry uncovered throughout the past two year's trial. The intent is to promote discussion in the BoM NTRG workshop in regards to IP telemetry.

The chosen IP (Internet Protocol) telemetry networks for DoW is either the NextG Telstra network or for remote areas the Globalstar satellite network. Other low orbit satellite systems such as Iridium are available but Globalstar offer by far the most attractive call plan and is the preferred satellite service.

Globalstar Orbit (114 minutes)



IP telemetry is different from dial up telemetry in that the site initiates the data transmission to a central server (static IP address). This occurs at a pre-determined period with transmission costs related to amount of data rather than connection time. Data are sent direct to a central server where it is stored, transferred, alarms managed and displayed as required. The current trial system transfers in near real time data from the IP server to Hydstra server. IP data can also be automatically sent via email to any other client(s) in csv format.

The amount of data transmitted from gauging stations is very small and call costs savings are realised compared to traditional dial–up methods. Up front capital costs of IP telemetry are high with starting costs being around $3,000 for a NextG system and $5,000 for a satellite system depending on model.

These approximate cost figures include logger and do not include housings, solar power, batteries and surge protection. These last 3 additional items are usually around the $1,000 mark. Housings are site dependant and can vary widely.

Where possible the NextG is the preferred choice with lower capital cost and low call cost plans of around $7 per month based on 10 minute transmissions. Provided good signal strength is available there should be no problems. The 10 minute intervals allow the user to stay within the 5mb per month plan and no additional fees are incurred. It is possible to transmit at 5 minute intervals but this will exceed the monthly allowance and cost extra. Note that although the amount of hydrometric data transmitted is small (just a few bytes) it is the nature of data packets in IP technology that the additional header and security overhead mean that each packet is around 1 kilobyte.

Globalstar satellite systems have had some bad press based on poor voice communications. Dropouts are common and in a dial-up situation it becomes almost useless. Iridium is not much better. However it is the nature of an IP system that it will keep attempting to establish communications until a satellite comes into view. Data is transmitted in a few seconds and problems associated with dial-up are not seen. This coupled with very low call costs makes Globalstar the most attractive low orbit satellite system in the market. Globalstar also have plans to put up additional satellites this year that will improve the service. The trial used hourly transmits and with combined monthly call and service fee average costs of around $50 per month were incurred. This is considerably less expensive than a MiniSat-M or Iridium satellite dial up system where call costs run at around $200 per month for daily unloads.

The nature of any low orbit satellite system is that there can be no guarantee of complete coverage at all times. Given most gauging stations are located in river valleys with either rocky gorge or heavy tree coverage, exposure to these satellites is often limited briefly to passes directly overhead. For the Globalstar network this can result in transmission delays of up to 3 hours. Generally most satellite transmissions succeed on the hourly setting. The chosen DoW system compensates for any failed transmissions by storing the data until a successful transmission occurs. The system will retry a number of times and upload only that data stored since the last successful transmission. The IP data logger can store up to 12 months of data (based on 2 x 2 byte channels) so if a major transmission failure occurs for a prolonged period, no data is lost.

ADVANTAGES OF IP TELEMETRY

- Almost real time. There is always a few minutes delay for NextG and an hour delay for satellite.
- Lower call costs for satellite. NextG are about the same as dial-up
- Data captured direct to central server. The server is the primary data source. The on-site logger is the back-up.
- Site visits are needs driven. There is no need to manually download data and visits would be to repair faults or carry out maintenance.
- On site photo capability.
- Accessible from any internet connection
- Site configuration is controlled from the server end.
- Satellite costs are about the same as dialup satellite costs

DISADVANTAGES OF IP TELEMETRY

- NextG IP capital costs are higher than dialup NextG
- Additional one-off server and server software costs. Cost varies with number of sites
- Logger and modem are bundled into a single package. Makes for more difficult faulty part replacement requiring whole system replacement. The number of spares that can be held will be limited. This is offset somewhat by the nature of the system in that faults can be observed from the office prior to departure.
- Complex spare management. Each field system has a variable IP address and this is tied to a site by a check system of terminal ID and site numbers. This makes changeovers tricky should a system fail. The IP terminal replacement identity has to be allocated at the server prior to the unit being installed.
- Possible security issues from www uninvited access

TRIAL BACKGROUND

The DoW's current dial-up telemetry and logger system which is maintained by the department's instrumentation support group, Hydrologic Technology Centre (HTC) incorporates a mix of approximately 56 satellite systems, 30 NextG, 50 GSM, and 50 landline. Provided cost savings are realised from the IP telemetry system then IP telemetry may expand to eventually cover the remaining 250 sites.

HTC has closely monitored the progress of IP technology and in 2007 noticed some suppliers attitudes to ownership and access to the data changed to allow agencies full control. Prior to this there was a concept that the supplier would operate the server and on sell the data to its clients. This was not acceptable to DoW and the HTC worked towards developing its own system. As every month passed more suppliers entered the market and IP telemetry became more widely available. With this increase in supplier competition, supplier attitudes changed. It was decided to shelve internal development and put out an Australia wide tender to supply (and develop) a system compatible with existing DoW installations. The trial was to include 5 NextG and 5 Globalstar IP telemetry systems. Unidata was the successful tenderer with their Neon IP system.

After the first 12 months it was decided to widen the trial with a further 5 satellite systems located in the Kimberley. This was to assess the effects of lightning and to test the new modifications resulting from issues uncovered with the initial 10 systems. It also tested the robustness of the systems in terms of transport and packaging. Surge protection was added to these systems and is not standard. To date none of these systems have failed.

The following is taken from the tender document and is included to detail the technical needs of an IP system:

TENDER SPECIFICATION

The DoW requires a trial system incorporating 5 satellite based telemetry sites and 5 NextG telemetry sites which communicate with a server by pushing data to the server over an Internet Protocol (IP) Terminal based network, or similar. The target is to change from a dial-up system of timed calls to a system where costs are based on volume of data. This phase of the new system will be limited to GlobalStar satellite and NextG communications technology .

The DoW has a requirement for supply, testing and delivery of:

An SDI-12 and momentary switch closure capable device Internet Protocol (IP) terminal) to perform the following functions:

- *retrieve data from SDI-12 sensors and switch closure devices;*
- *packet the data (or similar); and*
- *make data available for transmission by Globalstar satellite or NextG modem.*

The IP terminal between the SDI-12 sensor and modem shall have data storage capacity to ensure data is not lost if communications are interrupted.

IP TERMINAL SPECIFICATIONS

Transmission error and file integrity checking

Input

- *SDI-12 capable*
- *Momentary contact closure*

Data Storage Capability

- *Cyclic overwrite old data*
- *Capacity 3 months at 5 minute log interval for at least two inputs*

Data File Format

- *Non-proprietary ASCII*
- *One date time stamped record per line*
- *Unique file name made from site name and date/time*

Two IP Addresses

- *Primary server address*
- *Backup server address if primary fails*

Modem

- *Globalstar or NextG*
- *Possible RS-232 pass through to DoW logger*
- *Sim cards and connection arranged by DoW*

Alarms

- *User configurable*

The system must be delivered as a batch of 10 IP terminals with 5 satellite and 5 NextG modems complete with associated commissioning and support documentation and must be capable of communications with a DoW supplied server.

The IP terminal shall interface to existing SDI-12 transducers or SDI-12 compliant loggers, without disturbing the current operation of those data logging systems. The existing data logging systems, based on various loggers, record and report on a range of water measurement parameters. These transducers communicate via the SDI-12 communication protocol and/or contact closure. It is critical that the items proposed for supply meet the technical specification of the SDI-12 Support Group (see www.sdi-12.org).

TECHNICAL SPECIFICATIONS

The DoW requires that the package communicates to the supplied SDI-12 IP terminal in the field via IP based communications or similar. In responding, the respondent should note the following:

1. *The package must be in an industry standard development environment acceptable to DoW with ongoing support and development provided by the supplier.*

2. *The applications software shall allow for reprogramming of the interface either by direct cable connection or remotely from any PC. This will enable the download of new control files to allow for changes to the various operating parameters, eg reporting interval, logging interval and alarm conditions*

3. *The security method shall allow for file transfer control by user name and password.*

4. *Administrative functions shall be such things as setup of new IP terminal including upload frequency, alarm functions and so on to effectively administer the system.*

5. *The system must have the ability to implement error checking for file transfer integrity.*

6. *The package must be compatible with the existing DoW server system which has a static IP address, the hardware and operating system components of which will be provided and maintained by the department within the department's central IT area.*

IP TERMINAL

1. *The IP terminals will communicate over the internet using GlobalStar Satellite or NextG modems. (The preferred modem for NextG is the Modmax as this is currently being used by DoW). They will be capable of communicating to the DoW existing SDI-12 transducer range, contact closure and SDI-12 enabled logger instruments and uploading the data back to the central server. The IP terminal will also be able to receive updated configuration information from any secure PC by manual methods.*

2. *The IP terminal will communicate directly with the on-site SDI-12 transducers store and time stamp the data in a memory buffer capable of storing at least 3 months of 5 minute resolution data for two inputs. Time accuracy (±10 sec per month) is essential and the terminal shall incorporate an internal clock that can be reset remotely.*

3. *The IP terminal memory buffer will be cyclic and will overwrite old data when full. The terminal must be capable of dumping a selectable amount of data to server on command eg past hour, day, week month or year. (Note; the Globalstar system charges for 10 second windows [charged at 4c each] rather than data. It is essential we pack as much data as possible at 9600 baud into that 10 second window. Theoretically the amounts of data the DoW wishes to transmit are minimal but other header information may be a problem).*

4. *As a minimum the following sensor interfaces must be supported.*

   - *SDI-12 bus (1200 baud serial data communications to address specific transducers.)*
   - *Momentary dry contact closure, (Reed Switch device on rainfall tipping bucket)*
   - *(Direct logger communication not essential but may be useful to us and can be offered as an option)*

5. *Existing hardware at remote sites is to be utilised. If existing hardware cannot be used, the DoW will source a replacement or approve a replacement provided by equipment suppliers.*

6. *Data transmission will be from remote site to a server installed at the DoW by the departments IT infrastructure. Transmission will be by packet data (or similar) using Globalstar satellite system or NextG. Globalstar will only be used when NextG coverage is unavailable at that site.*

7. *The data from the IP terminal will be output as an ASCII file that is in a format acceptable to the DoW data processing package currently in use by the DoW. Eg. A typical time value series is (6 bytes for time and 2 bytes for each channel) in the format:*

   dd/mm/yyyy_hh:ii,vvvvvv,vvvvvv, etc (all leading zero's so fixed format)

   dd/mm/yyyy_hh:ii,vvvvvv,vvvvvv

   Where dd = day, mm= month, yyyy= year, hh= hour, ii= minute and vvvvvv = value

   When more than one SDI variable (channel) is to be transmitted the order will be user configurable.

   Each data file as received by the DoW server will be unique and will identify the site of origin. All DoW sites are uniquely numbered with up to eight (8) numbers but mostly six(6). eg. Site 616001 has an SDI sensor for water level, a tipping bucket rain gauge and a conductivity and temperature logger. The conductivity/temp logger data can be read as an SDI address. The file sent from this site at 0915hrs on 17/1/08 would look like:

   170120080915,10.123,0.0,10250.123,28.4

   where 10.123 is water level, 0.0 is rainfall, 10250.123 is conductivity and 28.4 is temperature

   This data file will be saved as 616001_170120080915.txt. The time stamp (or similar unique number) is needed such that if the internal transfer of this file from the DoW ftp server to the DoW Hydstra server fails, the data will not be lost or overwritten by the next transmission.

8. *All IP terminals will send data files to the same server directory (eg. \IPdata) on the DoW server. There is a need to have this data file also sent to a backup server if the primary server is off line. This will require the IP terminal to be able to be programmed with two destination server addresses; the primary and backup server. If transmission to the primary server fails the data will be sent to the backup server. From this point on the data will be handled by DoW. The DoW Hydstra software application will read this primary server directory and transfer the data to the Hydstra server.*

9. *The IP terminal should be able to be configured to handle alarm triggering of specified events that should result in the transmission of SMS and/or email message to nominated recipients. Alternatively, a file could be FTP'd to the normal server destination. The alarm criteria are to be adjustable by the user. (Note: this requirement is driven by the possible need to reduce satellite call costs by only sending a single daily data file. However if a flood event occurs in this scenario we need to know immediately. NextG systems will be transmitting continually and any alarm situations can be picked up at the server end.)*

10. *Proprietary data formats will not be acceptable.*

11. *The transmission of data must be verified guaranteeing the data integrity. If a data transmission fails, the system must retry a specific number of attempts until it receives confirmation that the transmission was successful. Following a failed transmission, the data must be stored and sent on the next successful connection.*

12. *The terminal must be able to be configured on site using a DoW field laptop running Windows software, and 'from the office' using either the DoW field laptop or desktop PC. This will probably be done via a standard internet connection.*

13. *On-line diagnostics may also be useful, eg battery voltage, usual ping etc. The IP terminal must monitor its on-line status and in the event it loses network connection it must attempt to reconnect automatically.*

14. *It is only desired to reconfigure the terminal, not on-site DoW data logger.*

TESTING

The DoW Hydrologic Technology Centre (HTC) will loan transducers to suppliers of terminal equipment for the purpose of testing their terminals on request.

Testing and acceptance will be as follows:

- *Supplier testing (can be done at the HTC if preferred) ;*
- *HTC workshop testing, followed by:*
  - *Initial on-site testing at eight (8) remote sites and two (2) test sites at the HTC.*
  - *During the testing phase changes to terminal operation hardware or software may be identified. These changes will be implemented by the supplier to the satisfaction of DoW.*

DoW STATIC IP ADDRESS SERVER

The server system shall be housed in the Department of Water's corporate data centre. The Department shall be responsible for maintenance of the server hardware, server operating system software and associated support, and operating system updates and the communications systems, internet connections and firewalls associated with the server. Typically, the Department would expect to make available a standard central server, for example a dedicated Windows 2003 server system, complete with operating system and operating system support and maintenance.

IP TERMINAL PHYSICAL SPECIFICATIONS

The IP Terminal must meet the following specifications:

1. *Supplied equipment must be 12 volt (nominal) power;*

2. *IP terminals must be low power and should utilise stand-by mode whenever possible. A 38Ahr battery should be able to power the terminal for up to 14 days during periods of heavy cloud cover*

3. *The IP terminals are to be installed by HTC staff inside IP65 or greater housing boxes, compatible with current DoW standards;*

4. *The IP terminals will be required to operate continuously in conditions of 10-90% relative humidity. Air temperatures will range from -10oC to +60oC and will include many months of operation with maximum temperatures in the +50oC to +60oC range; and*

5. *The ability of the IP terminal to accept immersion in water to a depth of 1 metre for a period of 24 hours would be an advantage.*

TRIAL NOTES

As with most complex systems, the initial specification and the delivered product changed as the project progressed. By some compromising and ongoing discussions with the supplier eventually a system suitable to both parties was produced. Some of the original DoW specifications could potentially harm the integrity of the system and were consequently dropped. For example transmission in ascii was considered too open to www hazards and programming of a terminal via laptop too risky from a server integrity point of view. The issue of a second IP address in the field terminal should the primary fail was not done as this aspect is better managed by the router in the server area of control.

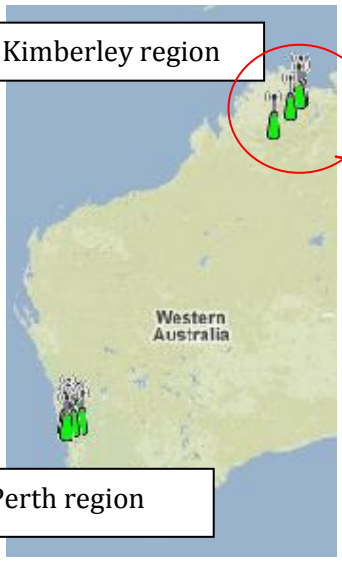
Trial objectives were to assess;

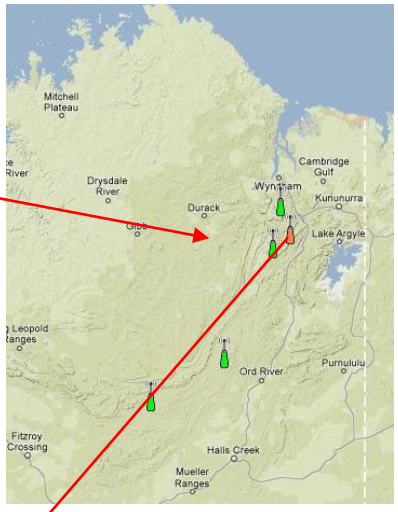
- The reliability of the technology over the long term (2 years).
- The physical issues in the system - ease of use, installation and servicing.
- Design shortcomings.

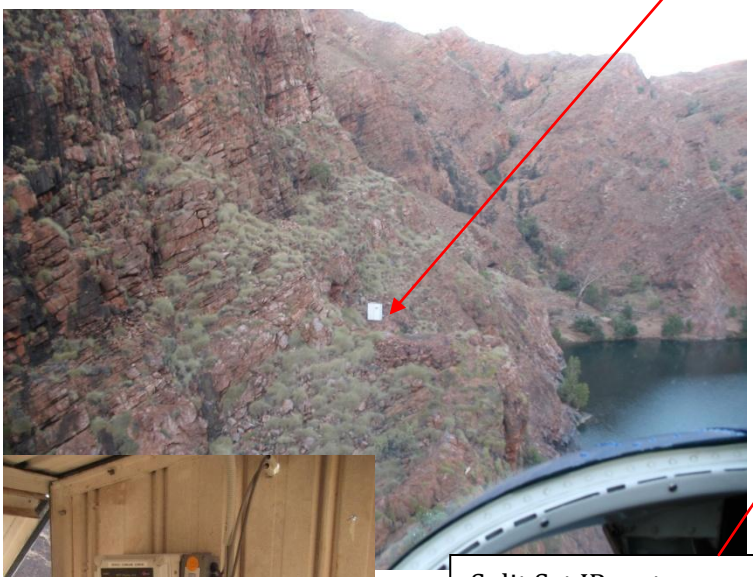
The physical characteristics of the NextG systems are straightforward whilst the satellite systems in the trial have issues with antenna mount limitations. Both systems had issues with emergency internal lithium battery backup capability and the need to power these off when re-setting a system. Original systems required actual battery removal but this has since been modified to include an external kill switch. It is expected many more refinements will be made as this really is a work in progress.

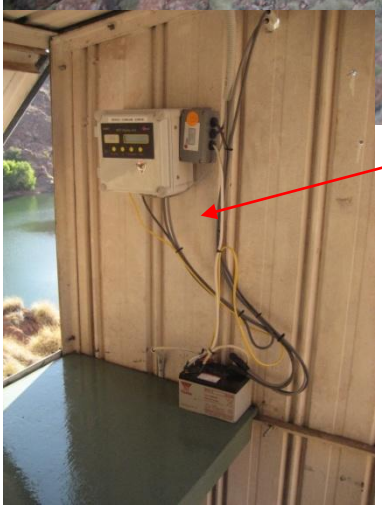
Several years ago DoW chose to adopt SDI-12 sensors as its standard hence the need for SDI-12 compatibility with any new logging system. A large part of the trial focussed around perfecting a SDI-12 system that would allow existing loggers to remain on site as backup. This in effect meant having two masters on the same SDI-12 bus. The problem with this is that at some point in time the two masters will attempt to simultaneously communicate on the SDI-12 bus. When a clash occurs such as this the result in some cases was a total lockup of either one or both masters. The final solution was to separate the two masters via an additional instrument that acts as a "SDI-12 listener". Data on the bus are then made available via the listener to the second master. The choice of which master has primary control is user configurable and should one fail the other will take over ensuring a failsafe system.

SITE LOCATIONS





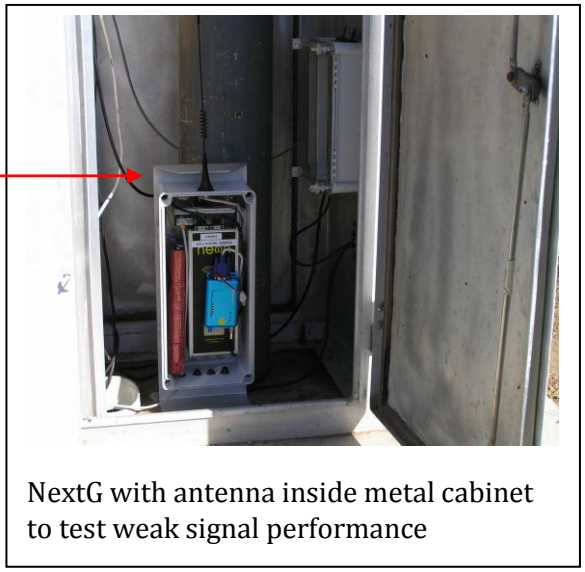




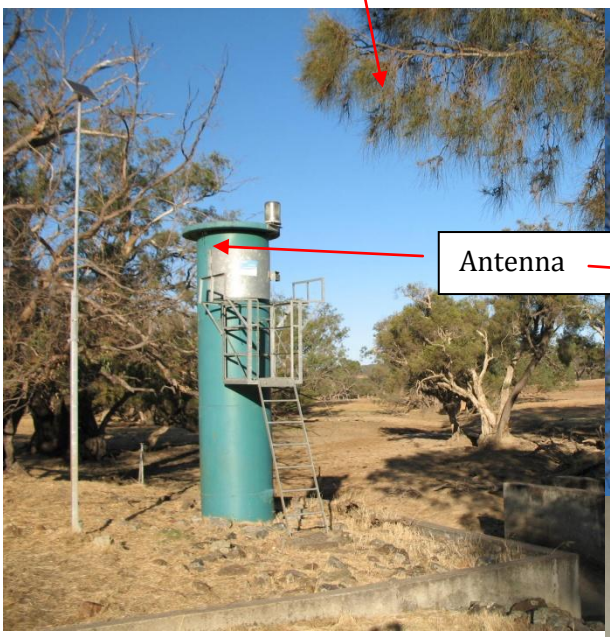
Split Sat IP system

Dunham River gauging station – Split IP system connected to gas system (WL3100 sensor) via Listener. Tipping bucket gauge uses dual output reed switch. See later plots of data

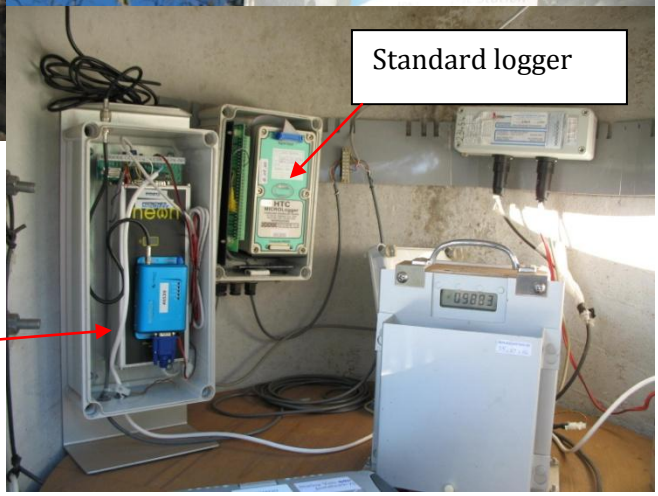
Perth Region Locations



NextG with antenna inside metal cabinet to test weak signal performance



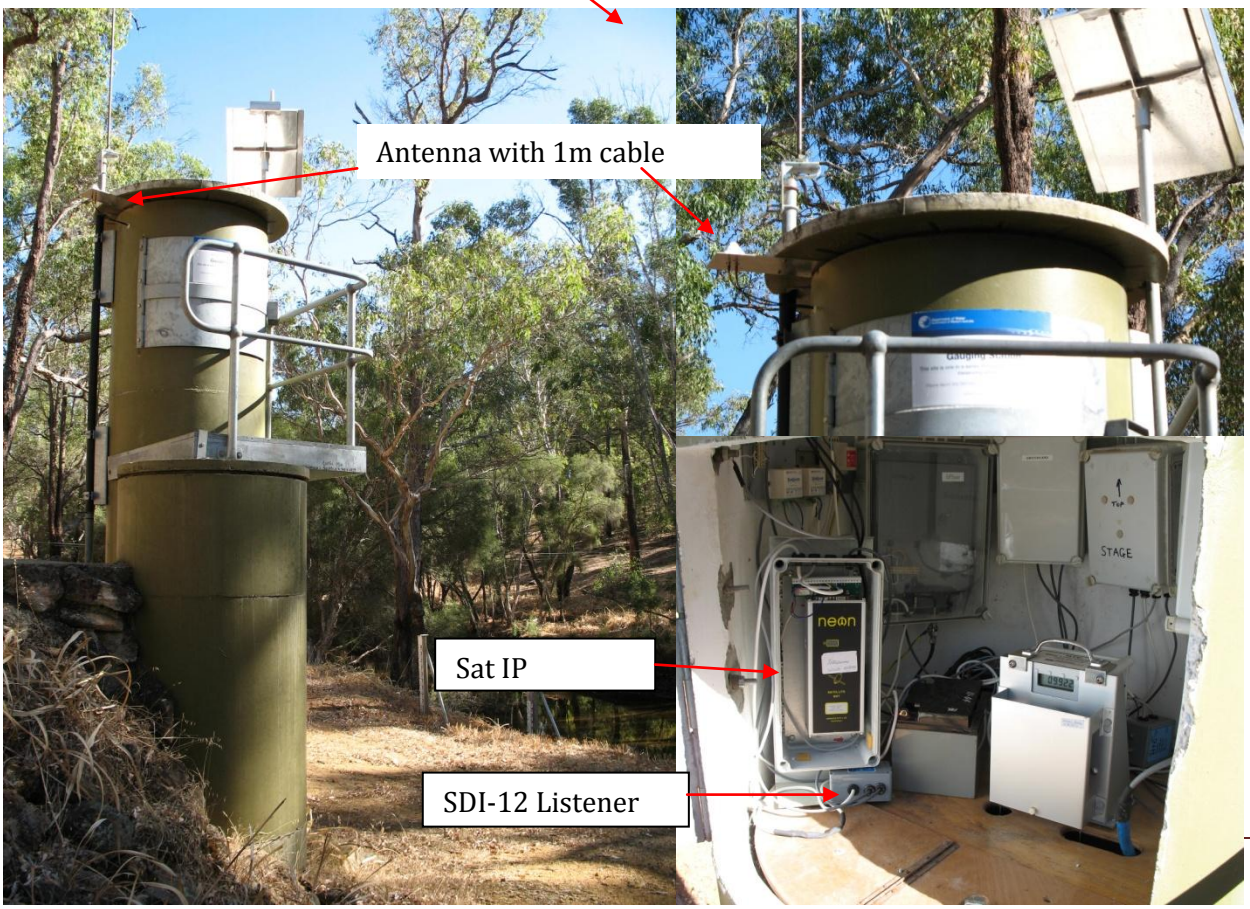
Antenna



Standard logger

NextG IP with Modmax modem

Sat IP system with 1m antenna lead



SDI-12 LISTENER

DoW existing logger fleet is half way through its replacement cycle and the SDI-12 Listener device is only necessary to ensure existing loggers can remain on site as backup. The IP system combines logger and modem and is quite capable of operating without any back-up. It is expected that as confidence grows with the IP systems the old loggers will be withdrawn from service. The listener will remain as a useful device should ever a second logger be needed.

Throughout the trial many IP system failures were attributable to SDI-12 clashes. An SDI-12 clash occurs when two masters on the same bus send commands at the exact same point in time. The nature of IP logger systems is that the timing remains correct (does not drift) as it is updated from the internet during connection sessions. Most standard loggers drift in time and this means that the timing elements between the two loggers will eventually clash when they are in perfect synch. Attempts were made to offset the SDI-12 commands in both loggers but eventually this time drift comes into effect. Sometimes it takes months, but it will happen! This results in sensor readings not getting through (flat line) or sometimes total logger failure i.e. the logger gets stuck in an endless loop waiting for an SDI-12 return message that never comes.

As design and modification of the device progressed the number and severity of failures diminished. The latest version of the device appears to be robust with no failures. It is interesting to note that as a spin–off from the trial several SDI-12 faults were uncovered within existing SDI-12 sensors. These have now been resolved and sensor manufacturers are now asked to include error checking with their sensor. This is standard with SDI version 1.3. The IP systems use error checking to ignore faulty SDI-12 values.

NEXTG SYSTEM.

All NextG test sites have good signal strength. To create a weak signal scenario 3 units were installed with the antenna placed inside the cabinet. Two cabinets are aluminium and one concrete. All 3 “bad” sites eventually had some issues in that the communications failed and the modems locked up. This took a few months to occur. Sites with “good” signal strength continue to work reliably.

As requested by DoW the trial used Modmax NextG modems as they are currently our standard. Unidata advised this may not be a good idea as some issues with this modem had been experienced and recommend the Sierra modem. Nevertheless the trial went ahead with the Modmax modem. Three of the five modems on test had problems and could only be resolved by changing the modems. Eventually a set of “good” modems was put in place. The problem was that occasionally the modem would lock-up and transmissions failed. Only by visiting the site and powering the modem off and on could the modem be reset. No real cause was found and it remains unresolved as to whether the problem was with the modem or the IP logger. It is believed the problem is to do with low signal strength as once the antenna was better placed the problems disappeared. However the issue of a modem locking up should not happen and it should be able to reset itself. The modems in the trial were purchased in the initial release just after NextG introduction and no doubt have since had improvements made. This is typical of this technology and trials date quickly.

SATELLITE SYSTEM

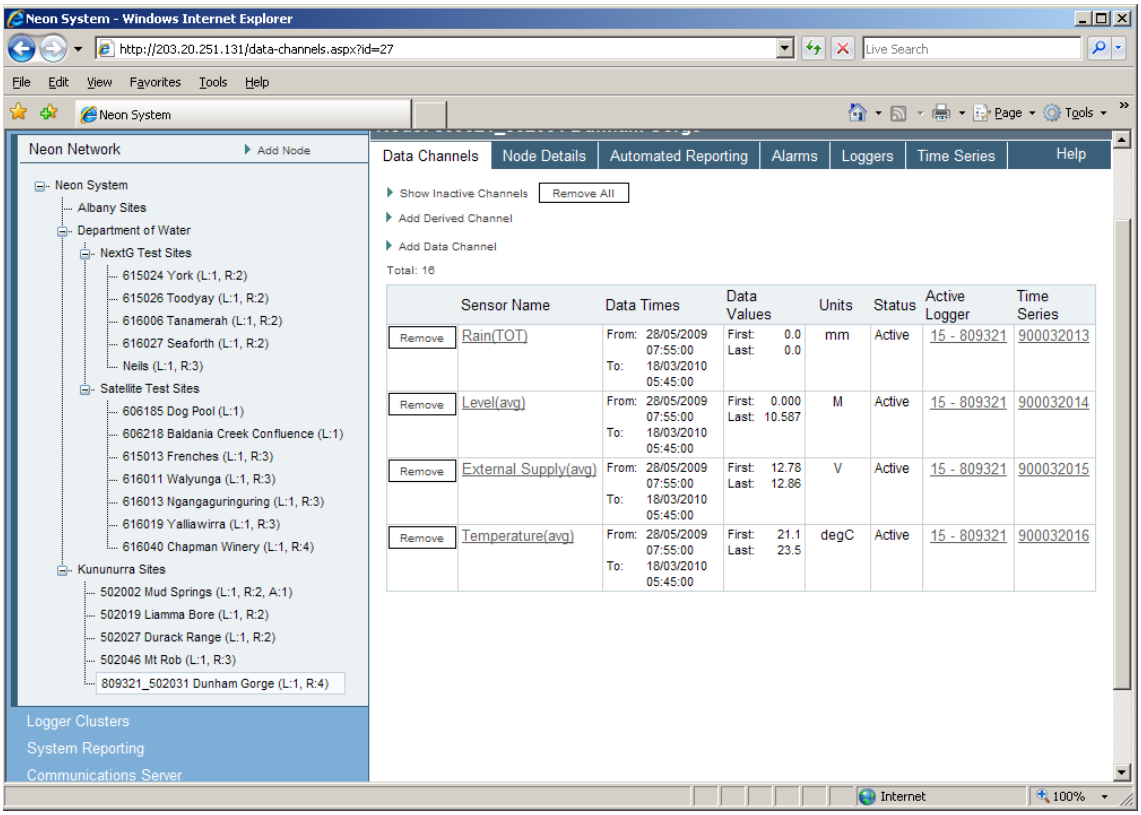
The main issue with this system is in the physical nature of the antenna hardware. A very short antenna lead will cause problems for some sites. According to the modem manufacturer the low modem power consumption can only be achieved with the short antenna lengths. At only 200mm there are severe limitations on positioning the system within an existing cabinet or shed. Early attempts by DoW to change to a high quality one metre antenna cable length resulted in complete instrument failure. The rigid nature of the leads stressed the connection on the modem board resulting in connection breakage. End result was expensive with total modem replacement necessary! This issue was remedied by fastening the antenna leads with cable ties to prevent any movement at the board end. However this voids warranty. As the trial progressed it was discovered that communications were in fact still acceptable with good quality antenna leads up to 2m in length. The issue of fastening to the board was resolved by simply adding a connector to the existing 200mm flexible leads. Depending on site needs a balance between signal loss (results in more missed communication sessions) and exposure to vandals will need to be made.

Twelve months into the trial Unidata had been made aware of these shortcomings and a split system was produced (see Kimberley photo). This allowed for a pole mount system with modem and logger housed up the pole and sensor connection with backup battery interface box located in the shed. The length of cable between the two is site specific and is limited by type of sensors connected. Theoretically the distance between the two could be tens of meters but longer lengths lead to induced surges. Splits systems were considered desirable in vandal prone sites where the antenna needs to be elevated but making the split system bullet proof or cyclone storm proof remains an issue.

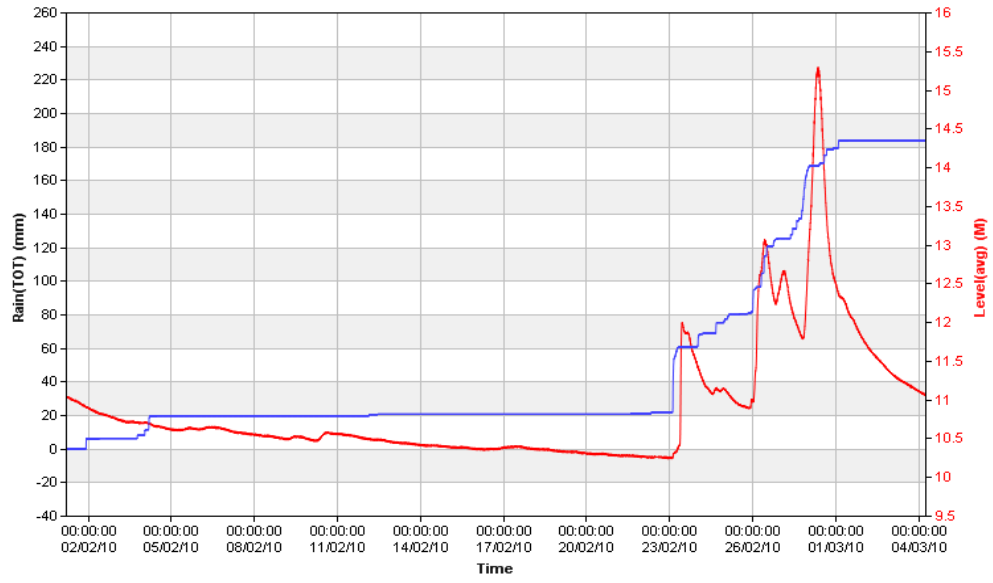
Surprisingly there were few problems with the Globalstar satellite network. Only one failure occurred throughout the trial with the W.A. Meekatharra based earth station going offline. This was resolved within 24 hours with no loss of data.

SERVER APPLICATION EXAMPLE

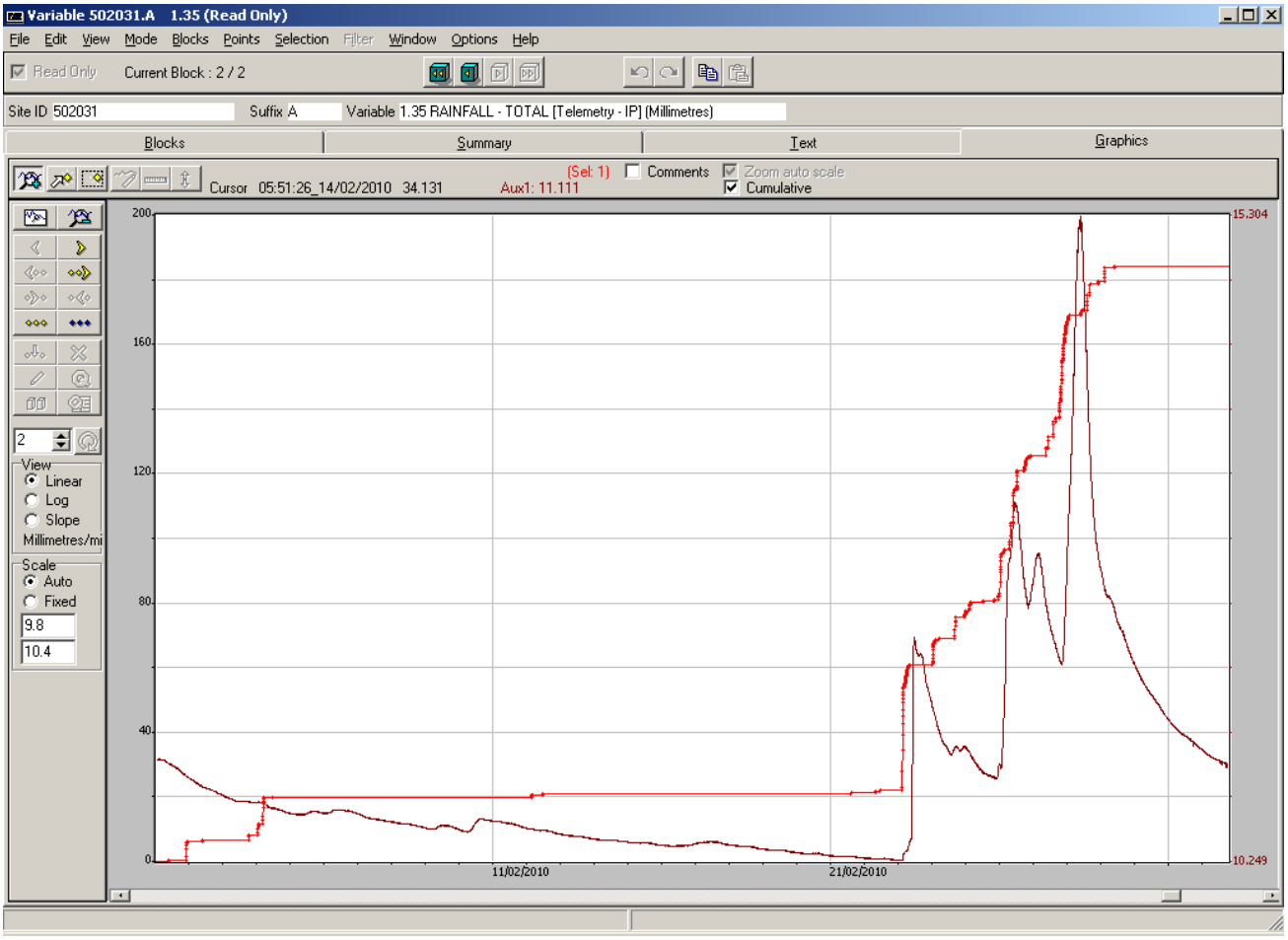
The server application allows for different user levels and is password protected. Site configuration files are downloaded to the site from the server when the site terminal makes a connection. Site connections can also be manually initiated from site. This normally happens when installing a site. Not a problem for NextG at 10 minute intervals but with satellite systems set at hourly intervals few field staff would want to wait this long. Only after the connection is made and the configuration files downloaded will the field operator know that the system is operational.



Neon plot of rain and river level of recent event on Dunham River (see previous photo) in Kimberley



Same event as archived in Hydstra. Data is transferred from Neon server to Hydstra server automatically in real time.



CONCLUSION

IP telemetry has proven to be a viable alternative to dial-up telemetry. Initial setup cost is high but ongoing call costs are lower. Throughout the trial few problems if any were associated with IP technology. Most problems were with the physical aspects of the site such as antenna location and operating the system in conjunction with existing loggers and sensors. After resolving the physical problems all systems operated very well with data moving seamlessly from site to IP server to Hydstra server.

In the two year period one satellite site had a glitch where "spam" corrupted the transmitted data (not the logger data) causing a single spike on all channels. This entry point has since been fixed by a firmware update that prevents unwanted intrusions in the site terminal. Overall the data appears to be well protected with checks in place to ensure all data gets through and is correct.

Historically we have always configured dial-up modems within the HTC. With IP telemetry it is important to allow the manufacturer to assemble the modem and logger as a complete unit. This allows thorough pre-testing by the manufacturer and avoids later disagreements about modem versus logger faults. Warranty covers the complete system.

Servicing is more difficult than dial-up as the systems combine both logger and modem. This makes handling of spares more expensive and carrying permanent spares in service vehicles is not desirable. Furthermore the IP system trialled has strict security checks in place that require the registration of the site terminal at the server end prior to installation. Unidata are aware of this issue and are working towards simplifying the process. It is best to pre-register the spares on the server before leaving the office. If this is not prearranged then for NextG it is possible to connect to the server from site and enter the necessary serial and site numbers. For satellite coverage areas operators must rely on a sat phone and relay details to someone with access to the server program. With IP technology it is expected that faults will be identified before leaving the office and the spare registered prior to departure. The ease of access to the data in real time will no doubt change the way we operate and should improve efficiencies.