Monitoring Safety of Tank Car Shipments

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ABSTRACT

Railroad tank cars are efficient vehicles for the transport of large quantities of liquid commodities in North America. These commodities include foodstuffs as well as a wide range of chemicals use in the process industries. Transport Canada and the U.S. Department of Transportation collaborate in the formulation of rules and regulations for the transportation of hazardous commodities. While the incidence of non-accident release (NARs) is very small there is nevertheless a further collaborative effort by shippers and car owners alike to reduce the incidence of NARs to zero. One approach in reducing NARs is to develop a means to identify small leaks immediately, while the vehicle is in transit. The IPRO team will identify and evaluate methods for detecting small leaks using car mounted sensors and alerting the shipper of the leak automatically form remote locations. This includes consideration of how to mount sensors and telemetry devices, log data, predict unacceptable trends and incidents, and report them in a timely, reliable and cost-effective fashion. The technologies involved in the development of such a system would include characterization of target chemicals, sensors and date transmission, mounting to the tank car, evaluation of the econ0omic viability of the concepts, and identification of potential legal implications.

Union tank car company

INTRODUCTION

Union Tank Car provides railroad tank and covered hopper cars to companies for the shipment of their products. Commodities shipped in tank and hopper cars are quite diversified. They include corn syrup, plastic pellets and resins, liquefied petroleum gas (LPG), various kinds of oils and acids, fertilizers, asphalt, sulfur - even tomato paste and beer!

Union Tank Car manufactures railroad tank cars in East Chicago, Indiana, and Sheldon, Texas. Our Canadian affiliate, Procor Limited, also manufactures cars - north of the border - in Oakville, Ontario. We also market plastics hopper cars built by Thrall Car Manufacturing Company.

Most cars are leased to our customers for three to five years. Full-service leases include the maintenance and administration expenses and taxes that customers would have to pay if they owned their own car.

Combined with Procor Limited, the company owns a fleet of approximately 70,000 railcars.
We repair, paint and apply interior coatings to tank and hopper cars at our network of repair shops located throughout North America. There are also many mobile repair units and minishops set up across the United States and Canada to handle light repairs at customer facilities.

HISTORY

The more things change, the more they stay the same," appropriately describes both ends of Union Tank Car Company's 100 years as the premier supplier in its business.

In 1891, as now, the nation fought a war over oil. The difference was that then, the battlegrounds were not overseas deserts, but the halls of the U.S. Congress. The government, armed with the newly-created Interstate Commerce Commission (ICC) and Sherman Antitrust Act, faced off against the Standard Oil Company, history's largest monopoly.

Standard was better known for lubrication than for transportation, but a key to its success was Union Tank Line, its railcar subsidiary. Standard leader John D. Rockefeller used tank cars as his "secret weapon" to dominate the industry by gaining control of oil shipping.

Oil refined into kerosene, was in big demand for lighting and other uses. The earliest tank cars were built in 1865 to transport oil from field wells. Although they were little more than two large wooden tubs mounted on a flatcar, they were much more efficient than previous shipping options. And within five years, an improved design using the now-familiar cylindrical iron tanks made tank cars the obvious transportation choice.

The trust and the bust

As Rockefeller spiraled upward in the oil industry, he expanded his domination of rail transportation by taking over several railcar supplier until almost all tank cars carried the now- familiar UTLX identification. When federal and state governments began flexing their new regulatory muscle against the monopoly, Union Tank Line was an obvious target. On July 14, 1891, the Standard trust dodged the legal assault by forming a "separate" corporation, the Union Tank Line Company, dedicated to transportation.

Though Union Tank Line was now technically independent, it was still owned by Standard Oil and served only the company's refineries. When the U.S. Supreme Court broke up Standard in 1911, Union Tank Line's 40 employees faced a new crisis. Previously the company's only mission was to provide efficient transportation for all Standard refineries. Now it had to make money as well.

Meanwhile, tank car design continued to evolve. Shortly after the turn of the century, cars with iron tanks banded onto wooden underframes were replaced by inventor John Van Dyke's steel "X-car" (named for the shape of its underframe), which connected tank to underframe with a specially-created anchor to keep the tank from shifting. The durable X-car permitted new commodities such as gasoline and chemicals to be shipped more safely. Heater pipes, another Van dyke innovation, opened tank car shipping to products such as paraffin and asphalt.

Standard's crude oil was no longer the only tank car lading, nor Union Tank Line the only tank car company. And the private car builders who had always supplied UTLX cars started to pursue new markets, including the Standard companies, directly.

Soaring and sinking times

In 1919 Union Tank Line bolstered its finances by listing on the New York Stock Exchange. Executives changed its name to Union Tank Car Company so investors wouldn't misperceive it as one of the railroads which had recently come under tight ICC regulation.

During the Roaring Twenties, the tank car industry stayed on track with American business prosperity. New markets emerged for chemicals, liquefied gas and foods. And the explosion in auto ownership increased the oil industry itself far beyond the six of John D. Rockefeller's empire.

As competition from other companies grew, Union Tank Car continued to focus on improving quality. Forge-welded tanks, better safety valves and double riveting made cars more dependable. Insulation and new heater pipe designs helped control temperatures of sensitive cargoes.

With the collapse of the nation's economy in the early 1930s, the number of surplus tank cars began to increase dramatically.Union Tank Car bought back thousands of cars from customers and eventually leased them as business recovered, launching a trend that continues today.

Throughout the thirties, the company continued to develop new types of cars and construction techniques. It pioneered use of the relatively new fusion welding process to increase tank strength, and as a result various products were able to be shipped under high pressure.

When World War II broke out, the threat of enemy submarines kept oil tankers off the seas, and tank cars became crucial to the wartime effort. Nearly 15,000 retired UTLX tank cars were sent to repair shops, where they were refurbished to haul oil in government-run unit trains.

Every day, more than 60 of these dedicated trains rushed oil from refineries to strategic locations across the country. They were hailed as "the stopgap between the dark threat of disaster and ultimate victory."

New markets, renaissance cars

When the war ended, the tank cars' dominant role in transporting bulk liquids was increasingly threatened by the growth of both oil pipelines and long-haul trucking. In response to this competitive threat, Union Tank Car launched an all-out effort to serve producers in emerging markets such as petrochemicals and fertilizers.

In 1954 the company unveiled a revolutionary new domeless tank car without an underframe. An underframeless car had been designed back in the early 1900s by John Van Dyke, but it was rejected then as unsafe. But UTLX engineers felt that in their new design, the tank arrangement actually improved the overall strength of the car. They also proved that the top dome, long considered necessary to hold product expansion during shipping, could be eliminated simply by filling the tank slightly less than full.

The new tank car, nicknamed the "Hot Dog" because of its appearance, shook 80 years of tradition and is still the standard of tank car construction today. Its flexible design spawned an unprecedented variety of cars customized to the needs of specialty chemical producers and other shippers.

Diversification, new owners

In the meantime, the company had acquired 20 other firms, many of which had nothing to do with tank cars. In 1969 the Trans Union Corporation was formed as the parent for all holding, and Union Tank Car refocused on rail transportation.

The most recent decade of UTLX history began with fiscal fireworks as Trans Union Corporation became part of The Marmon Group of companies in 1981. Union Tank Car continued as a separate company primarily dedicated to tank cars.

The 1980s saw computers enter the company's manufacturing process. Computer- aided design (CAD) of railcar components improved fit-up of car components. On the plant floor, computer-controlled lathe and robotic flame cutters and plasma burners literally put Union on the cutting edge of tank car quality.

The company continued to bolster its reputation for service. Mobile repair units traveled to customer sites, eliminating shop time for minor repairs and maintenance. And as most firms in the railcar business were scaling back operations, Union Tank Car expanded its service capabilities by opening a major new repair center in Georgia and merging the company's Lithcote lining and coating subsidiary into Union's overall service network.

Today-and beyond

Union Tank Car begins its second century with a strength that would probably impress even the demanding Rockefeller. Computers, robots and microwave technology make it a far cry from the company of 100 years ago that tracked cars by pasting sheets of paper to long roller shades.

Union Tank Car, along with its Canadian subsidiary Procor and its Mexican affiliate Carrotanques Unidos, is the largest tank car lessor in North American and one of the largest railcar manufacturers in the U.S. In addition to manufacturing plants in East Chicago, Indiana and Oakville, Ontario, the company has an extensive North American service network which includes 29 repair and maintenance locations, and seven lining and coating shops.

In the future, quality will continue to be the company's benchmark. "Since Union Tank Car's only mission for its first 20 years was provide flawless transportation services for the old Standard Oil Company, we emphasized customers over profits before it was fashionable," then noted company president Sidney Bonser. "Our goal for the next century is to not only meet, but exceed what customers expect from us."

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CHEMICALS
SHIPPED

<u>Chemicals Transported</u>

Shipped Commodities and their physical properties

A total about 100 chemical's list was obtained from BOE-6000-R, a book of shipping chemicals, which is provided by UTC. These are most often shipped chemicals and are transported by pressurized tank cars.

We did search on these chemicals and grouped them by different physical properties. It was found that most of these chemicals are gases at room temperature, some are between gases and liquids at a boiling point between 0C and 15C. There are about 40% of these compounds are flammable and about 30% of these chemicals with explosion range limit which indicate that if the concentration of these chemicals mixing with air fall in this range, a explosion will accrue. Some of the compounds are corrosive. Also, almost all these chemicals are toxic, and/or irritate. Vapor pressure and vapor density data were also collected.

Six most frequently shipped compounds and their physical properties were summarized in the following table. A list of about 100 chemicals with searched properties are also attached with this report.

Table of selected chemicals and their properties

Materials	**Physical State at RT**	**Explosive level in air**	**Vapor pressure**	**Vapor density**	**Flammability**	**Toxicity**
Chlorine	gas	-	4800mm/20^{0}C 7000mm/21.1^{0}C	2.48	no	Yes
Hydrogen chloride	gas	-	613 psi/21.1^{0}C	1.3	no	Yes
LPG (propane)	gas	upper 9.5% lower 2.1%	8.42 atm/21.1^{0}C 190 psi/37.7^{0}C	1.5	yes	Yes
Chloroethene	gas	upper33% lower 3.6%	19.2psi/20^{0}C	2.2	yes	Yes
Ethylene oxide	gas/liquid (bp.10.7C)	upper 100% lower 3.0%	-	1.5	yes	Yes
CO	gas	upper 74% lower 12.5%	-	0.97	yes	yes

How Physical and Chemical Property Related to Sensor Selection

Some sensors are designed based on the chemical properties of the analyte, this type of sensor get signal because of a chemical reaction such as oxidation or reduction of analyte. Some sensors are built because of the physical properties of analyte, the signal obtained is from measuring the light absorption and thermal conductivity. Another category of sensors are based on the properties of physical or chemical sorption on a coating of sensing surface, the signal measured are from the sorption caused changing such as light absorption, color and conductivity etc..

The chemicals on the shipping list are mostly hydrocarbons, halogen hydrocarbons and gases. They can be grouped by the properties of oxidizable and reducable or non-oxidizable and non-reducable. The oxidizable and reducable compounds such as CO, NO, H2S, NO2 gases can be analyzed by amperometric sensor (eletrochemical sensor). The chemicals which are difficult to be oxidized and reduced such as hydrocarbons and halogen hydrocarbons can be measured by Elastomer chemiresistor sensor (adsister sensor) which are measuring sorption caused signal change.

There are many type of sensors and all work differently depending on how they transduce existing chemical to a electrical signal. Amperometric gas sensor will respond to vapors or gases that can be electronically reduced or oxidized at an electrode surface. This sensor are very sensitive to most of the compound either oxidazable or reducible. Elastomer chemiresistor sensor which will respond to a large categories of gases and vapors include hydrocarbon compounds by measuring the electrical resistance difference caused by the conducting path broken when a gas adsorbs on the elastomeric conducting path.

There are many type of sensors and will be described at the following Part. Amperometric gas sensor and Elastomer chemiresistor sensor together with a oxygen sensor can hopefully cover about 90% of the compounds on this shipping list.

Conclusions:

Based on the properties we searched, transportation of these chemicals are potential hazard. Because many of these shipped chemicals have explosion limit below 3% in air such as LPG and ethylene oxide, also because of the flammability and toxicity issue, the sensitivity of sensor for detecting low level concentration should be considered. The type of sensor should be carefully selected for sensing a large group of chemicals.

Sensing the NARs

Sensors

Sensors can be categorized depending on how they transduce the presence of a chemical into an electrical signal. Reactive sensors generate a signal by measuring some aspect of chemical reaction of the analyte. Physical property sensors generally leave the analyte gas undisturbed, and measure some property such as absorption of light or thermal conductivity. Sorption sensors depend on the physical or chemical sorption of the analyte into a coating on the sensing surface.

Electrochemical Sensors – Also may be called the "porous-electrode amperometric gas sensor" or a fuel cell sensor. It responds to gases that can be electrolytically reduced or oxidized on a metallic catalyst such as platinum or gold. Typically gases measured are O2, CO, NO2, NO, and H2S, and organic vapors such as alcohols, aldehydes, or ketones. Typical sensitivities are in the 3-30 ppm range, but some proprietary sensors are capable of detecting as little as 2 ppb of gases such as ozone, NO2, H2S or arsine. Selectivity is generally modest unless auxiliary methods are used.

Solid State Semiconductor Sensors – This sensor typically consists of a bead of tin oxide formed around two fine coils of platinum wire. When the bead is heated using one of the coils, the analyte gas will oxidize on the bead surface, changing the electrical conductivity as measured between the heated and unheated coils. Nearly all oxidizable gases can be detected on this type of sensor. Selectivity is poor, but it can be modified slightly by changing the operating temperature and by doping the tin oxide with various elements. This type of sensor is inexpensive, but the sensitivity is not good (10-100ppm). There is also problems with baseline drift.

Combustible Gas Sensor – The electrical resistance of most metals will increase with temperature. The combustible gas sensor consists of a coil of platinum wire that is electrically heated. When gases combust on the surface, some of the heat of combustion is transferred to the wire coil. The increase in coil temperature is reflected as an increase in electrical resistance.

Flame Ionization Detector - The FID works by burning the analyte gas in a hydrogen flame. In this environment, organic compounds produce positive ions, which are collected at a cylindrical electrode above the flame. A very small current will be generated between the collector and the metal flame jet. The FID is very sensitive and linear over many orders of magnitude. Because of the needs for hydrogen and a mechanically stable environment for the flame, the resulting instruments are complex. FID is nearly non-selective among organic compounds, but they do limit their responses to organic compounds only.

Chemiluminescence – Certain chemical reactions generate light, which can be measured with great sensitivity.

Nondispersive Infrared – These are the simplest of the spectroscopic sensors. The key components are an infrared source, a light tube, an interference filter, and an infrared detector. The gas is pumped or diffused into the light tube, and the electronics measure the absorption of the characteristic wavelength of light. Usually quite expensive.

Spectroscopic Sensors – These use conventional means to generate monochromatic light in the ultraviolet or infrared and to measure its absorption by a gas. Specific organic compounds can sometimes be individually measured by measuring absorption of infrared light at one or more wavelengths.

Photoacoustic Sensors – If a short pulse of infrared light is passed through an absorbing gas, the absorbed light becomes heat. The sudden expansion of the gas generates a pressure, or acoustic wave, which can be measured with a microphone. These are variation of infrared spectroscopic sensors but the photoacoustic sensors measure the light absorbed by the sample where the conventional spectroscopy sensors measure light that is not absorbed.

Fiber-Optic – A thin glass or plastic fiber is coated with a thin layer of a compound that will absorb the analyte. When light is passed through the fiber and reflects from its inside surface, some of the light energy extends beyond the surface of the fiber. This effect is known as the evanescent wave, and its influence is usually no more than a few nanometers. A simple surface coating may absorb organic gases, changing its refractive index. The amount of light reflected inside the fiber is changed; this is detected by a receiver at the other end of the fiber from the light source. Other surface coatings may react with the analyte gas and change color, which will affect the spectrum of the reflected light.

Microbalances – The simplest form of this sensor uses a quartz crystal which is electronically made to vibrate at its natural frequency. The crystal is coated with a material that absorbs the analyte gas. The mass of the coating increases and slows down the natural rate of vibration of the crystal. The resulting frequency shifts can be measured electronically with great sensitivity. This class of sensors is also sometimes referred to as gravimetric.

Conductive Polymer – Certain polymers are electrically conductive. The conductivity changes when certain gases are absorbed by the polymers. The polymers can also be tuned to certain compounds by carrying out the polymerization in the presence of the analyte.

Adsistor – These measure the very slight physical expansion of a film of an elastomeric material that occurs when it absorbs a gas. The elastomer contains electrically conductive particles such as carbon. The concentration of particles is adjusted so that there are relatively few conducting paths through the elastomer. Slight expansion of the elastomer causes some of these paths to be broken, and the electrical resistance rapidly increases,

Reactive-Gate Semiconductor Devices – Some use voltage directly applied to the gate to control the flow of charge carriers, others use a chemical interaction to change the transconductance.

Environmental Market holds Promise for Chemical Sensor Systems

A recent market study commissioned by the Characterization, Monitoring, and Sensor Technology Crosscutting Program (CMST-CP) within the Department of Energy's Office of Science and Technology (EM-50) shows environmental market potential for chemical sensors systems. These sensor systems offer field measurement opportunities for site remediators.

Ideal Specifications for Sensing Element

size	2” x 1” x 6”
weight	3 lbs
cost	$1000
speed of response	seconds to minutes to alarm state
sensitivity	10’s to 100’s ppm for most chemicals (typically 0.1 to 10 times required alarm level)
range of selectivity	as many commodities as possible (see list)
stability	1 year minimum between maintenance cycles
self diagnostic	Yes
rugged	continue to operate for 1 year under normal tank car conditions (vibration, environment)
reporting	NAR alarm (once a day), catastrophic alarm (immediately)
outside shield	stainless steel, aluminum, or ABS plastic
car location	on demand

Sensor Discussion

All of the above sensors where researched and considered. A constraint that a device around the valve housings of a moving pressurized tank car would have is power. The Adsistor and the electrochemical sensors where chosen because of their low power requirements. The Adsistor and the electrochemical sensors would only need power when inquiring the sensors of their results.

The electrochemical sensors chosen were the CO and O2 sensors. The CO sensor was chosen to specifically measure carbon monoxide because of its toxicity. The oxygen sensor was chosen as a back-up system. If the Adsistor sensor or the CO electrochemical sensor did not detect the leak, the displacement of oxygen by the leaking gas would be detected by the oxygen sensor.

The Adsistor Sensor

The Adsistor sensor looks like a small resistor. It is specially coated to make it sensitive to gas vapors. The base of the coating is a non-conductive, resilient polymer that holds in place conductive particles. The phenomena of adsorption are the basis for the sensor's sensitivity. In an ambient air environment, the particles, each independently anchored on the polymer surface, are in contact with each other, forming an electrical path. When a contaminant vapor comes in contact with the particle surface, a mono-layer of contaminant molecules is adsorbed onto the particle surfaces. Van der Waal's adsorption forces cause separation between each of the particles increasing the electrical path's resistance. The electrical resistance measured across the Adsistor is determined by the amount and type of gas molecules adsorbed to its surface. Therefore the Adsistor requires no power to operate and is monitored by measuring its resistance like a common resistor.

Adsistor sensor data can be collected by measuring the sensor's electrical resistance. The resistance is related to the concentration for most gas vapor concentrations by the following equation:

$$R = R_B 10^{\frac{C}{K}}$$

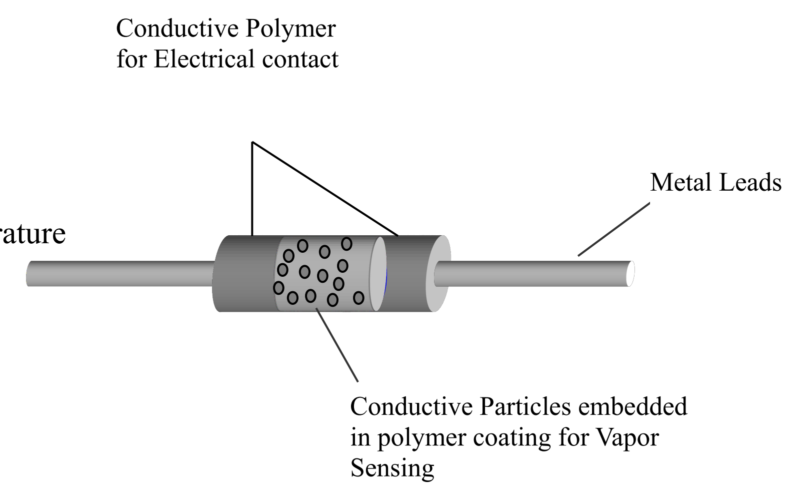
where

R = Measured resistance

RB = Resistance in clean air

k = Gas constant at ambient temperature

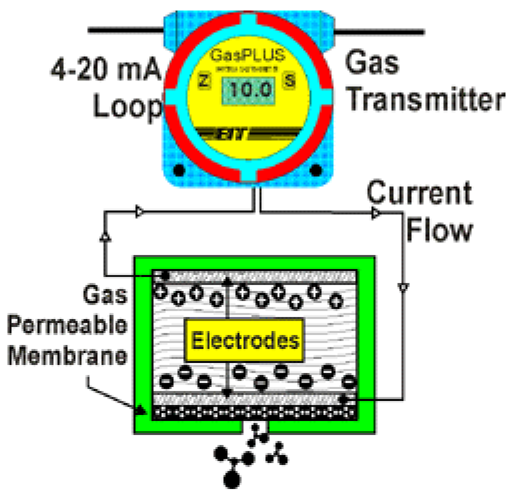
c = Gas concentration (ppm)



The Adsistor sensor resistance versus concentration should be a straight line when plotted on a semi-log graph.

The Electrochemical Sensors

An electrochemical sensor generally has three main components: electrodes (one or more of which is coated with a catalyst), electrolyte, and a membrane. Gas diffuses through the membrane and reacts at the electrolyte-catalyst interface, which creates a current. The instrument measures the current and translates it into gas concentration. Since the number of electrons give off is proportional to gas concentration, sensor output is linear.



The sensor lifetime is determined by many factors including heat, humidity, dirt, and cumulative gas exposure. Under normal operating conditions, sensors should last for at least one year, and in many cases two years. Brief exposure to high concentrations of gas can reduce sensor performance in the near term – gas that has worked its way into the sensor (response time) needs time to work its way out (recovery time.)

Although the sensor output is linear, response time is a logarithmic function. The first molecules of gas to diffuse through the membrane cause a very rapid change in response; as the sensor's output approaches the actual ambient gas concentration, the rate of change of response slowly decreases. The response curve of the best sensors looks very much like a step function; that of the worst looks more like a straight line. The inverse of the response curve determines a sensor's recovery time after being exposed to gas.

Manufactures typically define some length of time, such as 10 minutes, as the point at which a sensor reaches its maximum output. A sensor's T_{90} is the time in which it reaches 90% of this value; T_{50} is the time to reach 50%. The lower these two numbers, the better the sensor's performance.

Most electrochemical sensors require a fixed bias to be maintained across the sensor electrodes. This bias is one of the key determinants of sensor performance; after it is applied, the electrolyte typically needs time to reach equilibrium. For most sensors this warm-up period is 4-8 hours. However, some manufacturers provide sensors with a built-in battery that maintains bias, thus eliminating warm-up time.

All electrochemical sensors experience zero drift. However, typically this is a long-term phenomenon, and quarterly calibration is generally adequate to compensate for it. Interferents, gases other than the target gas cause the sensor to respond, are a nearer-term concern; their effects are often mistaken for drift. Since they are related to the electrolyte composition, interferents cannot be eliminated. Careful positioning of gas detectors during design and installation can help prevent interference problems.

Sensor electrolytes are generally hygroscopic, meaning the amount of water in the electrolyte tends to reach equilibrium with that in the surrounding air. Because water is a key part of the electrochemical reaction, in very dry areas sensor lifetime will be diminished. Similarly, in environments with very high continuous relative humidity, sensors will have a shortened life.

Rapid air flow past a sensor's face (typically greater than 1 liter per minute) can change gas diffusion characteristics, which can affect sensor performance. In addition, high air velocities can reduce sensor lifetime by drying out the sensor more rapidly than normal.

Wireless Solutions

Telemetry Solution :

After the NARs have been successfully detected from the tank cars, the issue which arises next is the transmission of the signal so as to indicate if the release have gone above the permissible limits. This signal can be possibly an alarm which can inform the shipper about the NAR.

Wireless Data Communications

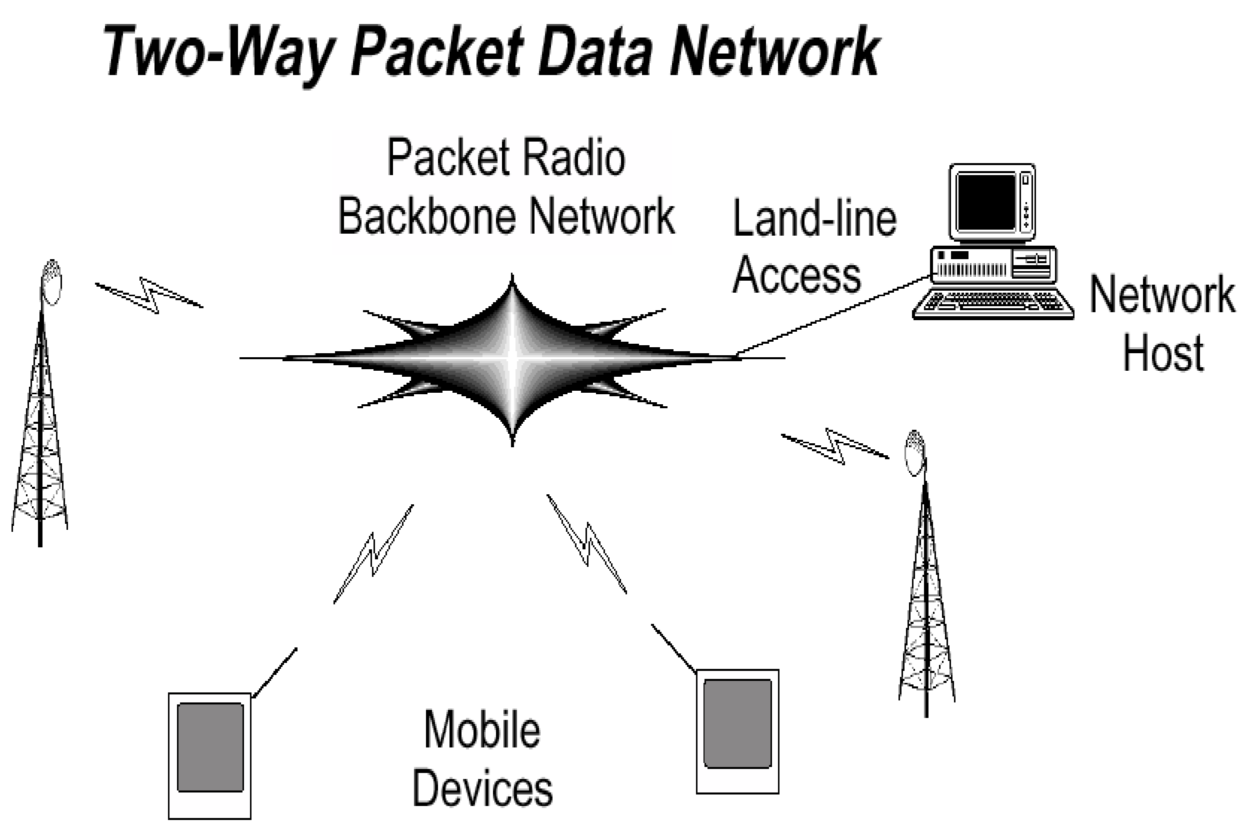
The Options :

While developing or enabling an application to transmit data wirelessly, it's a good idea to first give some consideration to the environment in which the application will operate. What mobile device will the application reside on and what network will transport the data? What host platform will be used and how will it be connected to the network?

The ever-increasing number of application programming interfaces (APIs) and middleware products available for wireless applications has enabled the application to be more independent of the device and the network. However, complete independence is not yet a reality, and it's most effective to make the decisions regarding the environment(s) in which the application will operate before beginning development. There is no "right" place, and a decision in one area might affect the possibilities in others.

- **Two-Way Wide-Area Packet Data Networks**

Two-way wide-area packet data networks are owned and operated by service providers that offer wireless data communications to the public. Private networks, used by fleet operators and support services such as police, fire, and ambulance services, also use this type of network. The networks are designed for data transmissions only and use infrastructures of base stations, network control centers, and switches to transmit the data. Enterprise systems (corporations) and third-party service providers can connect host data systems (servers) to the network via phone lines. Depending on the network, customers might pay a one-time fee to establish the connection and register devices with the network, a monthly fee to subscribe to the network, and fees for each message transmitted. Charges are based on the amount of data transmitted, not the connect time.Packet data networks allow many devices to share a small number of commu-nication frequencies, making such networks more economical to operate than similar circuit-switched networks. Transmission speeds vary from 4800 bps to 19.2 kbps. However, the actual transmission time and throughput is determined by the network load and overhead and cannot be precisely specified. During peak hours, data moves more slowly. Mobile users with devices registered with a network can roam freely between network base stations that are set up to provide coverage throughout the network. Roaming from coverage area to coverage area is seamless and trans-parent to the user.



Two-way wide-area packet networks send information in packets (also called datagrams and message units). Two-way messaging means that messages can be transmitted as well as received. The networks provide for the acknowledg-ment of messages successfully delivered and guarantee message integrity through the retransmission of messages received with errors. They can store messages and forward them when the modem is turned on or when the unit is back in coverage area. Users can configure their message confirmation and delivery options to meet their organization's needs most effectively. Since packet -switched data networks typically use fewer radio frequencies than circuit-switched data networks, delays in transmissions make wide-area packet-data networks most useful for sending small (less than 2k) amounts of data in each message. Wireless WANs are not ideal for online sessions or large file transfers. ARDIS and RAM are the two largest packet data public networks in the U.S., each covering all major urban and suburban areas. Applications designed for use in metropolitan areas across the country can expect excellent coverage using either of these networks. Applications targeted at rural areas need to verify coverage. ARDIS is based on the Motorola DataTAC network technology and RAM uses the Mobitex network technology. Both technologies use open standards to encourage third-party development of both hardware and software, so subscribers will have the widest array of options possible. This openness also ensures compatibility among devices produced by different manufacturers.

DataTAC Networks

DataTAC networks are in operation around the world, in the following countries :

These DataTAC networks come in the following three “flavors.”:

• **The DataTAC 4000 networks, which operate in North America**:

• ARDIS, U.S.A.

• Bell Mobility ARDIS, Canada

• **The DataTAC 5000 networks, which operate in Asia and the Pacific:**

• Motorola Air Communications Ltd., Hong Kong

• CELCOM, Cellular Communications Network, Malaysia

• SINGTEL, Singapore Telecommunications Ltd., Singapore

• TAC, Total Access Communications, Thailand

• Telstra, Australia

• **The DataTAC 6000 networks, which operate in Europe:**

• DeTeMobil, Deutsche Telekom DataTAC Networks

DataTAC networks are being developed in many other countries as well. Applications developed for one DataTAC network can be used in another with minimal modification, particularly if an application programming interface like AirMobile is used for development. However, due to regulatory constraints and frequency differences, most devices are country-specific. The differences among the DataTAC networks include the following:

• **<u>The radio frequenc</u>**<u>y</u> : DataTAC 4000 and 5000 systems use 800 MHz frequencies, while DataTAC 6000 systems use frequencies in the UHF (400 MHz range). This means that different radios are required.

• The use of frequencies. Multi-frequency reuse (MFR) is used by DataTAC 5000 and 6000 networks and single-frequency reuse (SFR) is used by DataTAC 4000 networks.

• **The radio protocol**s. Over the air (between the host and the modem), DataTAC 5000 networks use the RD-LAP protocol operating at 19.2 kbps. DataTAC 6000 networks use RD-LAP, operating at 9.6 kbps. DataTAC 4000 networks offer the MDC protocol, operating at 4800 bps, throughout their coverage area and the RD-LAP protocol at 19.2 kbps to accommodate traffic volumes in major metropolitan areas. The dual protocol nature of the ARDIS network is handled by dual-protocol software in Motorola's new modems and personal communicators.

DataTAC networks provide host-to-client routing and peer-to-peer routing Host-to-client routing is suited for applications that require central control functionality or interoperability with other networks or fixed systems. A dedicated private line can be run between the customer or service provider's server and the network. In peer-to-peer routing, wireless devices exchange messages with other wireless devices without having to route the messages through an outside server. ARDIS PersonalMessaging, which allows subscribers within a work group to send messages to one another, is an example of peer-to-peer routing.

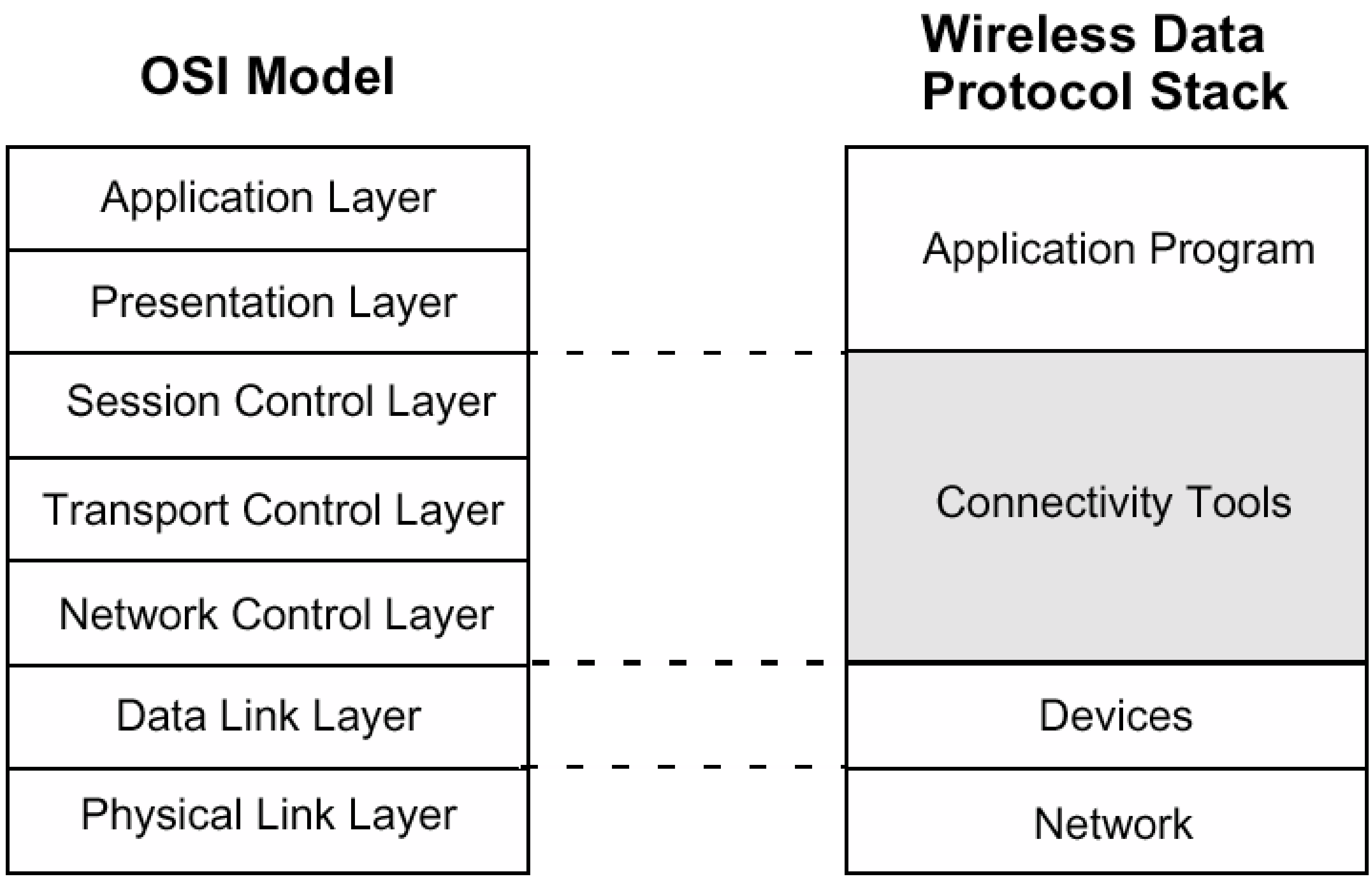
External Wireless Modems

External wireless modems, such as the Motorola InfoTA device, are connected to a laptop computer using the serial communication port. They enable users to send wireless e-mail and to access corporate applications and other more vertical two-way wireless data applications such as dispatching and two-way paging. The InfoTAC device is an external wireless modem that is small and light enough to carry in your hand. Versions are available for both DataTAC and Mobitex networks. It relies on its own power supply, communications software, and user interface. The InfoTAC device can be used in the following ways:

• As an acknowledgment pager. The InfoTAC device notifies message senders that the user has successfully and accurately received the incoming message.
• As a two-way messaging device. When a message is received, the user can respond with a preprogrammed response, such as approval of a request or the estimated time of arrival. The device receives and stores messages in a reserved 10k message buffer.
• As a modem connected to a portable computer via an RS-232 port. The Info-TAC device enables data transmission over the wireless networks from laptop-based applications.

InfoTAC devices can be used on all DataTAC and Mobitex networks.
Many other external wireless modems are on the market.

Motorola also manufactures the MRM(Mobile Radio Modem) for the OEM market. The MRM is an external modem that allows virtually any computing device that can communicate over a standard RS-232 link to operate in a wire-less environment. The modem is compact, environmentally rugged, and highly reliable. The power output of the MRM is one or three watts. The MRM is specifically designed for wireless communications with such portable computing devices as laptop computers while in a vehicle. Its chassis makes it suitable for in-dash mounting. The MRM can receive and store messages on a continuous basis when the portable computing device is not in operation. Its RAM contents can be maintained for several days during vehicle power disruptions.


OSI Model
Application Layer
Presentation Layer
Session Control Layer
Transport Control Layer
Network Control Layer
Data Link Layer
Physical Link Layer
Wireless Data Protocol Stack
Application Program
Connectivity Tools
Devices
Network

Using the experience gained in successfully implementing wireless solutions, ARDIS has developed an **end-to-end solution** approach. This approach separates a wireless solution into four key components:

I. <u>Application Software: Client and Server</u>

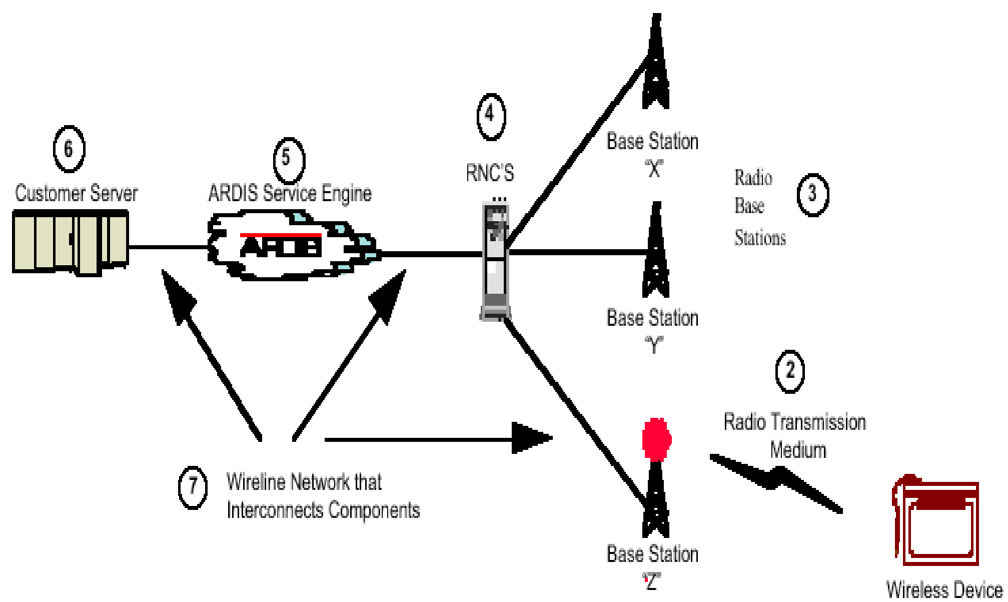
Application software encompasses the software pieces at the two ends of the data system: the client software contained at the wireless device (the client programs) and the software contained at the host (serversystem). These two pieces represent a significant part of the development effort (under full control of the developer). They contain the user interface software, the client application, as well as the processing of the information at the server end. The development effort may require these pieces to be created from scratch; or may require extension of the capabilities of a current application (i.e. converting a wireline application to wireless). In either case, the application should be optimized for wireless data communications to meet price and performance requirements.

<u>II. Connectivity Components</u>

Connectivity components are the communication interfaces to the ARDIS network from the application software. On the client side, it includes the layer of communication software which stands between the client application and the radio modem. It also includes the protocols needed to interface with the ARDIS network. On the server side, it may include a data line and hardware components (such as an X.3 PAD related to an X.25 connection), along with the communication software and protocols to send data from and to the ARDIS network The development effort may require these connectivity components to be custom created; or they may be purchased from a wireless provider and configured for a specific application. If an existing application is to be used, a connectivity component may take the form of a gateway, whereby incoming data traffic (to the gateway) is altered to fit the communication components on the other side.

III. The ARDIS Network

The ARDIS network is the focal point for the transference of data. Communication towers, switching centers, and wireline network paths all work in conjunction with switching processors to provide a reliable and secure communication path. What we take for granted as simple wireline connectivity is replaced with a complex network infrastructure when the application is written for wireless. The developer needs to view the ARDIS network as a given. The connectivity component provides the integration to the ARDIS network, but this does not mean that the developer should ignore the network aspects and consider it to be merely a wireline replacement. Network features, performance, and network characterization must all be identified and understood by the developer of wireless applications.



IV. Wireless Devices

Finally, there is the wireless device to be considered. There are many fully integrated wireless devices and combinations of computer-radio modem packages available which offer a variety of feature/functions.Those best suited for the application must be selected prior to application development. The wireless device chosen may arise from a marketing or business decision, and may point to the platform that the client development will take place on. The ARDIS network provides wireless data users with fast and reliable access to host computers, network gateways, and to other users. Because ARDIS allows the user to process information at the point of occurrence, he/she can improve responsiveness, accuracy, quality of service and customer satisfaction. In short, it gives the user back his/her most valuable asset: time. Saved time equals saved money. Experience indicates that the payback period on investments in ARDIS solutions are often less than one year.

Wireless communication over ARDIS frees the user from many of the limitations imposed by typical information systems. There is the freedom from having to locate a telephone or to go to a location containing a data terminal each and every time the user wishes to communicate. It offers freedom from time limitations which may dictate when and how often the user wishes to communicate. Wireless access is available any time and virtually anywhere for the mobile user.Wireless communication is part of the explosion we are experiencing in teleprocessing systems. Delivery of information accomplished by interlinking many systems is making more information available than ever before. As the availability increases, data transmission is becoming as indispensable to modern individuals and groups as their electricity supply. Information is an asset that feeds business success, provides security, educates, provides a base for decisions and other key business activities. However, it must be managed properly. The nature and usefulness of information, the timing of when it is needed, and economics of delivery must all be taken into consideration. Since wireless communication imposes a premium on the cost of delivery, the nature and content of the communication must be managed even further. Depending on the system it may be more economical, and faster, to send data via wireline systems. Wireline systems offer the luxury of fast transmission rates from client to server; and a large amount of information can be passed to low cost. For wireless transmissions, the developer should place an emphasis on the real-time transference of information;

using a minimum number of bytes and ignore related information that does not have to be sent. The developed system may not appear to be as elegant as its wireline counterpart from a user interface perspective, but managing the nature and content of the message is critical from an economics perspective.

Wireless Data Networks

DataTAC Networks: Network Phone Number

Australia Telstra 61-2-911-3153 outside Australia

800-633-785 within Australia

Canada Bell Mobility ARDIS 514-333-3336

Germany DeTe Mobil 49-228-936-7450

Hong Kong Motorola Air Communications 852-599-2868

Malaysia CELCOM 69-3-263-5770

Singapore Singtel 65-838-2656

Thailand UCOM 662-248-7240

U.S.A. ARDIS 708-913-1215

Mobitex Networks:

Australia United Wireless 61-2-241-5290

Belgium RAM Mobile Data Belgium 32-2-715-25 11

Canada Cantel 416-229-1400

France France Telecom Mobile Data 33 (1) 43 95 73 64

France TDR 33-1-46-12-30-00

Germany GFD 49-201-02054/926-285

Hong Kong Hutchison Mobile Data 852-599-2800

Netherlands RAM Mobile Data Netherlands 31-3465-82611

U.K. RAM Mobile Data U.K. 44-181-990-9090

U.S.A. RAM Mobile Data U.S. 908-602-5500

U.S.A. BellSouth Mobile Data 404-249-5000

CDPD Networks:

Overview Of Series 500 External Modem

Wireless data messaging on DataTAC systems requires the use of different communications protocols to control how the system hands off messages between the DTE, the modem, the RF network, and the fixed-end host. These guidelines describe how to format the messages using the status send and serial modes. These communication protocols provide a means for certain types of OEM devices to communicate across the network. To support these devices, Motorola manufacturers Series 500 integrated wireless modems in a PC Card Type III form factor. The modem allows input from triggers and sensors, and it includes a serial communications interface. Modem software release 4.1 and above supports three modes of modem communications:

• Native mode, which frames all packets sent between the PC and the modem. This mode is more demanding to implement, but it allows the DTE application easier control of the modem. Refer to the *Native Control Language 1.2 Reference Manual* (part number 6804025C15) for additional information.

• Status send mode, which allows the modem to send trigger and sensor data to a pre-defined destination. This mode is easier to implement than native mode, though it provides less flexibility for controlling the modem.

• Serial mode, which allows the modem to generate unframed messages on its own to send all data on the serial port to a pre-defined destination. By default, status send and serial modes are both simultaneously operational. Native mode, however, operates mutually exclusively from both of these modes.

Features :

The Status Send II feature provides the following data communications capabilities :

Status Send Mode of Operation

• The modem monitors four input lines for state changes (pins 16-19).

• The four input lines are polled every 50 mS with PowerSave OFF or every second with PowerSave ON.

Status Send Mode of Operation

Input line monitoring to trigger event reporting to the fixed host.

Serial Mode of Operation Simple serial interface PAD for easy two-way communication

Remote Command Facility Remote access polling and control functions from the host.

Automatic Off Auto-off for unattended battery powered operation.

Preconfigured Packet Routing

All addressing and routing information required to deliver data packets to the remote host can be configured into the modem.

• Each of the four input lines can be triggered on a single or configurable number of transitions on that input line.

• The modem can buffer up to 32 triggered uplink status send message notifications.

• The fixed-end host can remotely poll input lines and counters.

Serial Mode of Operation

• The modem acts as a PAD (packet assembler/disassembler).

• Any data received on the serial port will be sent into the network

• The modem can buffer up to eight uplink "packets" of data received on the serial port.

• Each packet can be up to 2048 bytes.

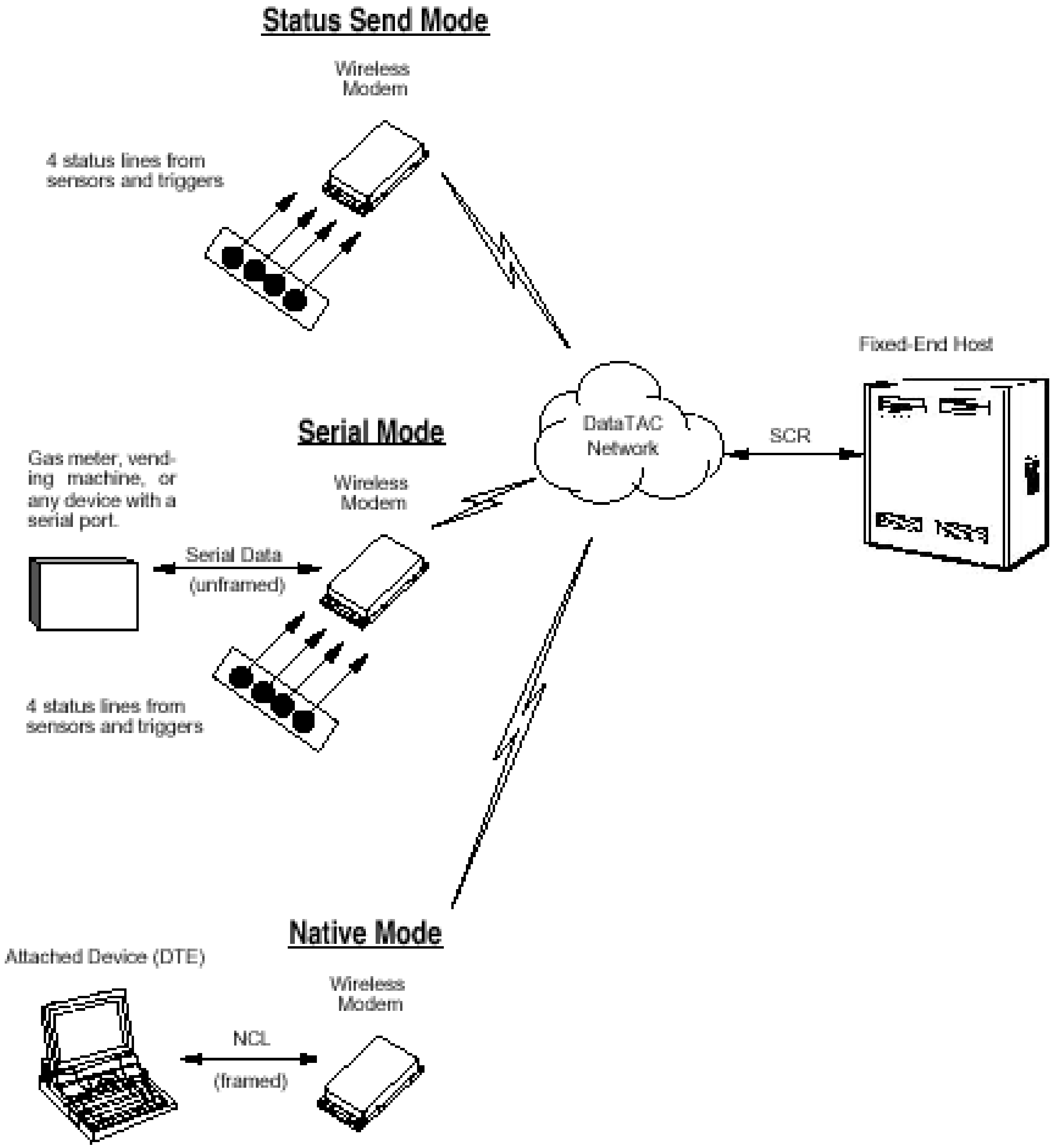
• The modem automatically prepends a preconfigured packet routing header to each uplink packet.

• The modem continues to attempt delivery of messages until they are successfully sent to the network. A programmable timer can set the interval between automatic retries.

• Downlink packets received from the network have the header stripped. The remaining data is passed out the serial port to the DTE. The number of header characters to be stripped can be programmed in the personality of the modem.

• The serial port supports these lines: DCD, DTR, DSR, RTS, CTS, RI.

• The modem supports a configurable baud rates (300 bps - 9600 bps) with two fram-ing and parity options: even/7/1 and none/8/1.



• Packetization occurs via a configurable packet terminator character or a timeout between characters. The default is timed transmission.

• The modem uses RTS/CTS flow control (XON/XOFF is not supported).

Automatic Off

• The automatic off feature can be enabled by a personality setting.
• When the auto-off timer expires, the modem deregisters from the network, drops DSR, and enters low-power mode.
• The host device can remove modem power as soon as DSR goes low, indicating shut-down is complete.
• The host must toggle the Host_Power_On line to reactivate the modem.

Preconfigured Packet Routing

• A configurable header is prepended to each packet.
• Messages can be routed to either fixed-end hosts or RF loopback hosts.
• Packets originated from either serial or status send modes of operation can be routed to different fixed-end hosts.
• The modem has configurable retry interval range of 2 to 60 minutes, with a default of 10 minutes.

Possible Applications

The features of status send and serial modes offer a number of interesting implementation possibilities, some of which are introduced here:
• The auto-off feature can be used where no power or phone lines are available. While using a single 9 volt battery, the modem can be powered on to send a message when-ever an alarm triggers. After a number of seconds, the modem powers itself down and drops the DSR line, signaling the attached device that it can remove power until the next alarm condition is encountered. If only one or two alarms per month are encountered, the system can run for over a year from a single 9 volt cell.
• Conversely, the modem can be always powered on and programmed to signal an attached device to wake (by pulsing the Ring Indicator line) whenever a message is received from the network. Since the modem is fully PowerSave compliant, it is able to sleep and wake up at known intervals expected by the network, thus saving power

without losing any messages.

• Any serial device such as a GPS receiver can be connected directly to the modem serial port. The modem acts as a permanently connected pipe that sends all serial data to a default fixed-end host. There is no need for ATD commands since the modem is always connected to the same fixed-end host. Similarly, any data received

Modem Configuration Issues

Consider the following issues when configuring the modem:

• Configure the modem by using MPS (level 5) or the Status Send Configuration Utility.

• Select the PowerSave feature as ON or OFF.

• The preconfigured packet routing header can be set to use either fleet-style or DM-style headers.

• It is possible to turn off battery low and modem reset event notification by enabling the Status event suppression field.

• The retransmission persistence timeout can be adjustable to 2 - 60 minutes.

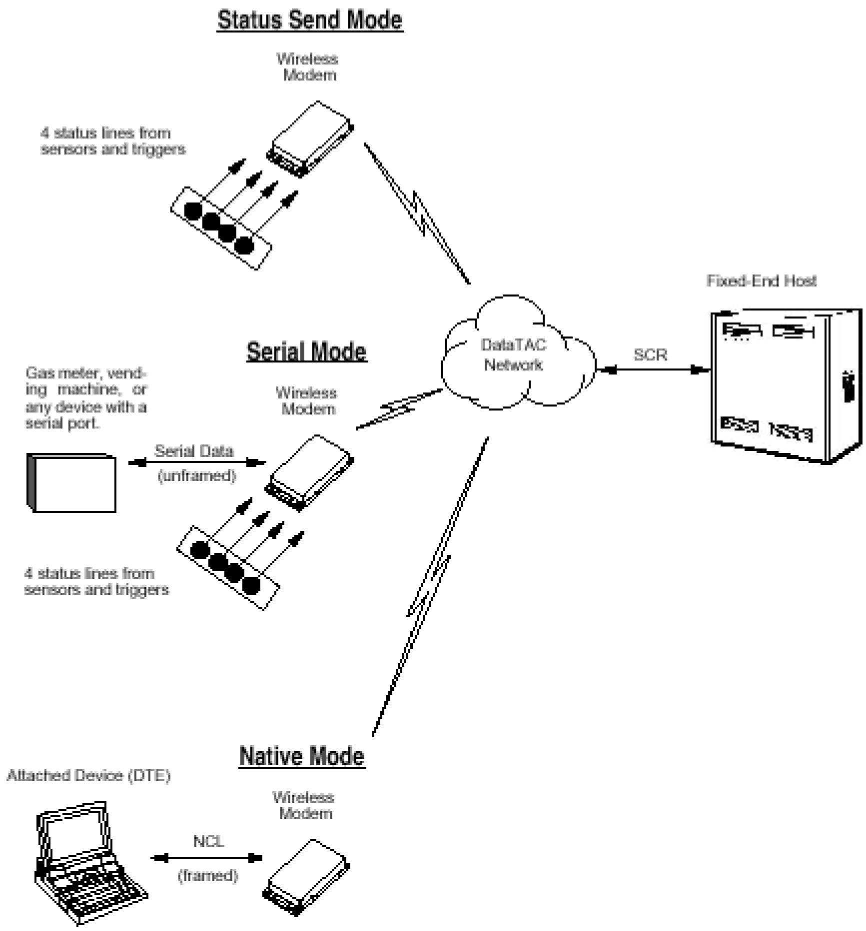
• Serial interface characteristics, such as baud, parity, and stop bits, can be configured in personality.

• The auto-off timer feature can be enabled by using the configuration utility.

With multiple simultaneous message streams possible (one from the status lines, one from the serial port), it is necessary for the fixed-end host to determine the source of the message. To accommodate this, the modem can be configured to send to either the same fixed-end host or two different hosts. In a single fixed-end host configuration, it is still possible to determine the sender by examining the first bytes (the user header field) of the header, which are unique in each case. As an additional option, it is possible to use DM style peer-to-peer communications for both status line and serial mode communications.

Power Supply Considerations

Since Series 500 modems are used in many battery powered applications, it has been designed to minimize power consumption. The modem defaults to PowerSave on, which allows the modem to sleep most of the time, waking up at known intervals only, when the network might send a message. The serial input lines use low power 3 V CMOS levels instead of 12 V RS232 levels. Also, the modem has separate 7.2 V and 5 V supplies to the radio and logic boards, respectively, thus minimizing excess current. The RAM backup supply at 3.3 V has been designed so that it requires optional power only when needed, thus saving additional circuitry costs. In situations where power is not a consideration (such as when mains power or large battery capacity are available), it may be best to use a different approach to supplying power. The modem can be configured to disable PowerSave, which reduces the message latency from the network. Accordingly, it may be more economical to provide a single power source to the modem. To facilitate this, both the 7.2 V and 5 V power lines are capable of accepting up to 9 V from a single supply, allowing direct connection of an off-the-shelf 9 V battery for low cost implementations.



Status Send Mode
Wireless Modem
4 status lines from sensors and triggers
Fixed-End Host
Serial Mode
DataTAC Network
SCR
Gas meter, vending machine, or any device with a serial port.
Wireless Modem
Serial Data
(unframed)
4 status lines from sensors and triggers
Native Mode
Attached Device (DTE)
Wireless Modem
NCL
(framed)

Conclusions

CONCLUSION

- Use of Adsistor along with the O_2 and CO electrochemical sensors

- Use of Series 500 Modem (SD505) along with ARDIS network support Need for further testing and development before a prototype can be built.

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