BNSF's Use of Low Band Radio Frequency Packet Technologies for Safety Overlays

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The BNSF Railway is using low band RF technologies in the 44 Mhz band along with the Global Positioning System and Geographic Information Systems to do a variety of functions that add to a more safe and efficient operation.

Locomotives, Hy-rail vehicles, Failed Equipment Detectors, Warm Bearing Detectors, and Wind Speed Indicators are using this technology and have increased safety and efficiency of railway operations.

Locomotives have been equipped with this technology to report fuel usage and monitor its position and relate this position to the railroad geographics.

Hy-rail vehicles are also equipped with this technology to alert the dispatcher and Hy-rail operator of the vehicles location and if it is in compliance with its authority to occupy the main track.

Winds Speed indicator systems on BNSF are using the technology to deliver Wind speed, direction, humidity and Wind speed trends over time. This information is integrated into the dispatcher system for decision-making. Field personnel can also monitor this information for local use.

Elimination of dedicated point-to-point technologies is facilitated by this low band, packet technology and will allow for less network infrastructure maintenance.

FED and HBD Design and Usage:

The level of heat emanating from Rail Car journals is an indicator of the bearing condition. Excessive heat can be created by a variety of negative bearing conditions. Once the heat has reached a critical level, the bearing will fail and the result is a damaged journal and a possible derailment.

Detecting this event is the job of our HBDs, or Hot Bearing Detectors. These detectors are placed at trackside across the rail system. To date, their function has been to detect and alert a train crew, via the voice radio, when a hot bearing is detected in it's consist. The *Warm Bearing Project* is hoping to take this a step further by using statistically measured data from multiple detector readings to *predict* the failure of a bearing instead of just alarming after it has failed.

Attempts to use journal temperatures to predict bearing failure have been ongoing for over twenty years. Previous efforts have not provided the necessary reliability in prediction to make the effort worthwhile.

After a sizeable derailment at the U.P. in the summer of 2001, investigation determined that the data previously collected on the journals for the train could have predicted the incident. That led to the joint BNSF and U.P. development of the "Outlier" algorithm for predicting these events.

The U.P. determined that the HBDs on their system were taking 8 million bearing measurements a day. Of these, only 1000 measurements were statistically outside of the 75^{th} percentile of the distribution. When looking at those "Outliers", only 20 bearings were repeated at more than one HBD location. This was a very manageable data set with significant correlation to the bearing failures. Accuracy is important so those failing bearings are identified and insignificant "detections" do not stop trains unnecessarily. Both BNSF and the U.P. believe there is significant value in further developing this predictive application. Byron Dickey in the Mechanical department leads BNSF in this effort.

The key to making good use of the application is to obtain timely data. Until now, all of the HBD locations were accessed via a dial-up connection to extract the consist bearing data. Many of these dial lines were actually cellular phone connections due to the difficulty of getting a telephone line from the local service provider. The cost for some of these dial connections can be significant and the reliability is often poor. Recent implementation of the Hy-Rail Limits Compliance Project (HLCP) has provided a low-bandwidth wireless solution to this connectivity problem.

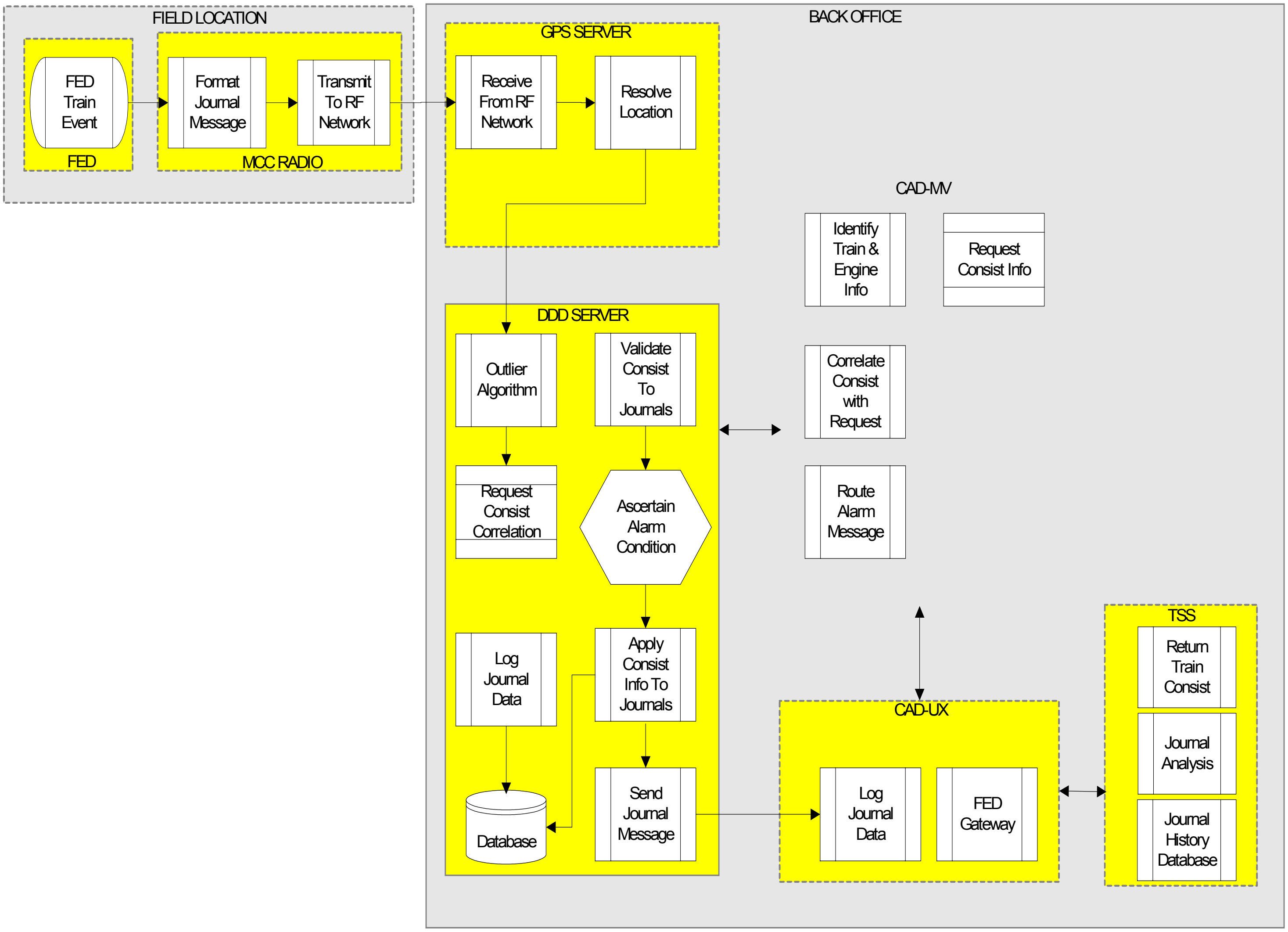
A low-band VHF half-duplex packet radio system, manufactured and managed by Meteor Communications Corporation (http://www.meteorcomm.com), has been installed across the main routes of the BNSF. The *Warm Bearing* Project is piggybacking onto this system by installing detector site Meteorcomm radios that will convey the HBD data from the wayside into the BNSF network. A typical installation is shown in the photos. The larger antenna is the Meteorcomm / HBD system.

Warm Bearing Detector with Low Band Radio Frequency System

The next illustration is the System View of the *Warm Bearing* Project design. This diagram identifies the physical entities used in the application. The field section shows the formatting, compressing and transporting of the HBD data into the GPS Server, located in Ft. Worth. The GPS Server identifies the location of the detector then forwards the information to the DDD (D-cubed) Server that processes the information as an "event" with support from the CAD system. If an "alarm" condition is detected, that message is handled in the CAD system. The information is then retained in databases and stored into the TSS mainframe Journal History database.

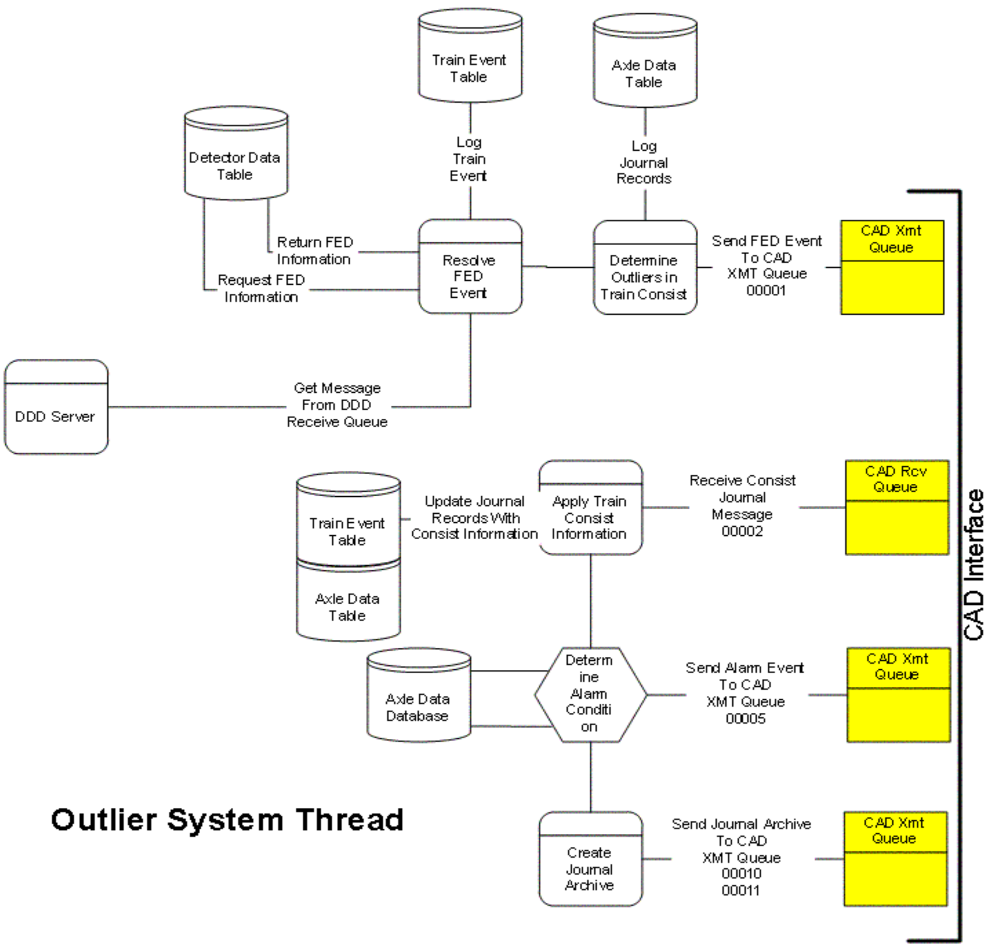
The last diagram illustrates the logical process flows for the application.

Those closest to the project are confident that the Outlier algorithm will provide the predictive capability to improve the handling of heated bearing issues and thereby improve the performance of train movement. The ability to make use of the existing wireless packet data infrastructure is “icing on the cake” because it provides a low-cost and reliable method to bring in the essential wayside data.



Warm Bearing Detection Project

Systems Overview



Outlier System Thread

Wind Speed Indicators using Low Band Radio Frequencies:

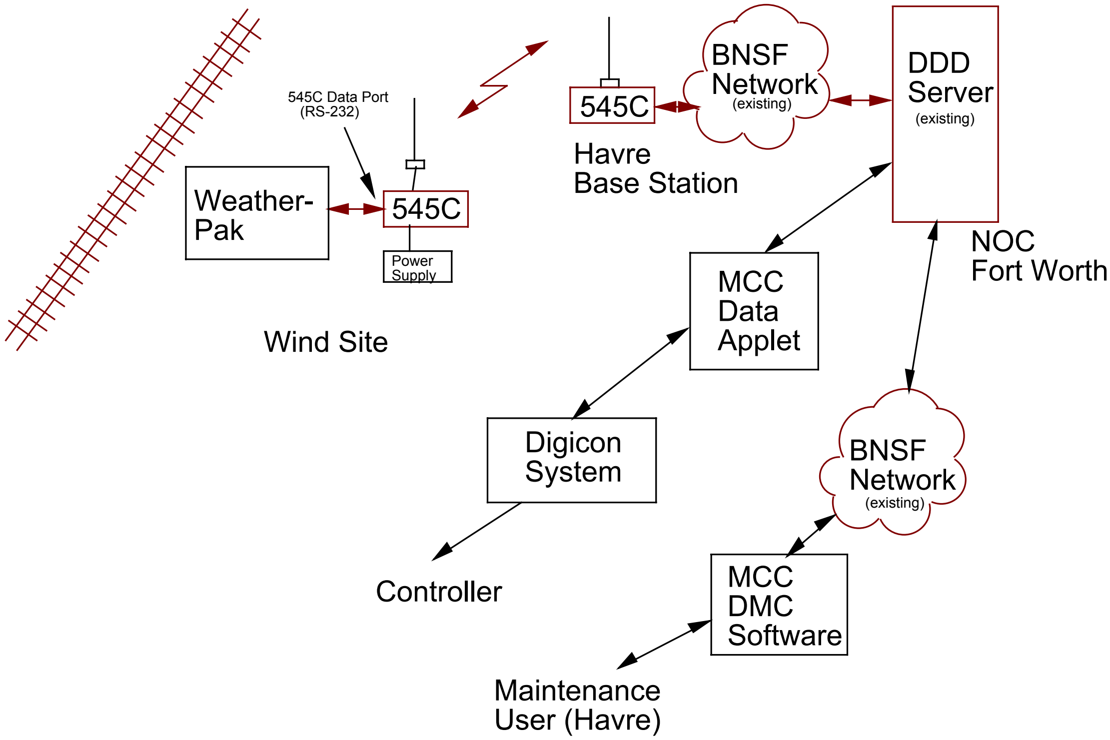
Wind Speed Indicators provide BNSF dispatchers and operations personnel with weather related data from the field. The intent of this system is to enhance the wind speed monitoring within BNSF in order to prevent derailments caused by high wind or rain. A primary reason for low band RF technology in this application involves increasing the reliability of the field weather data that is sent to the dispatch center. Previous data links involved dedicated 9.6 circuits from the field locations to the office. By moving the weather data into a packet network we increase reliability, scalability and delivery of the data across a fault tolerant network.

The Wind Speed Indicator Project is a packet data network consisting of remote weather stations and low band RF connected base stations. BNSF utilizes the WeatherPAK-2000 system, a complete self-contained weather station, to monitor trackside weather conditions. The WeatherPAK-2000 will produce 70-100 bytes of comma-delimited text once a minute, which will efficiently transmit over the BNSF low band 44 MHz HLCS network. The radios used in the HLCS network are MCC-545C packet data radios supplied by Meteor Communications, Inc. (Meteorcomm). The MCC-545C radios will relay data between the remote stations and the BSNF WAN, which connects to the Network Operations Center (NOC). Wind data will be routed through the NOC on the Ethernet network for distribution by the MCC's Dynamic Data Distributor (D3) routing software, which will route to multiple destinations. The data is integrated into an existing server in the NOC, where Digicon, an in-house designed program, is used to interface, and display data on the dispatcher workstation. The data will also be routed to the BNSF sites and will be transmitted directly to the weather service provider, Weather Data, Inc., to utilize their archiving services.

Figure 4, on the next page, outlines the network functional connections used by the Wind Monitoring Station. The WeatherPak interfaces to the MCC-545C Packet Radio using the RS-232 Data Port. Wind Data is passed to the MCC-545C using SDATA format.

The data is transmitted to the Base Station, which is connected to the existing BNSF NOC in Fort Worth. From here the data is feed to the Meteorcomm DDD router which is currently running in Fort Worth. This router sends copies of the data to the BNSF wind server (also running at Fort Worth), which converts the data into the format needed by the Digicon System and then passes the data to the Digicon System and presents the data to a web page that is updated every 30 seconds.

The DDD router also passes a copy of the data back out the BNSF Network to remote locations and to the MCC Data Monitor and Control software. This software stores the data in a local database and monitors the data for extreme conditions (such as high winds or bad sensor readings). DMC can generate alerts on these conditions or on the absence of data. DMC can also send commands to the 545C at the Wind Site for maintenance and troubleshooting purposes.



Wind Monitor Network Drawing

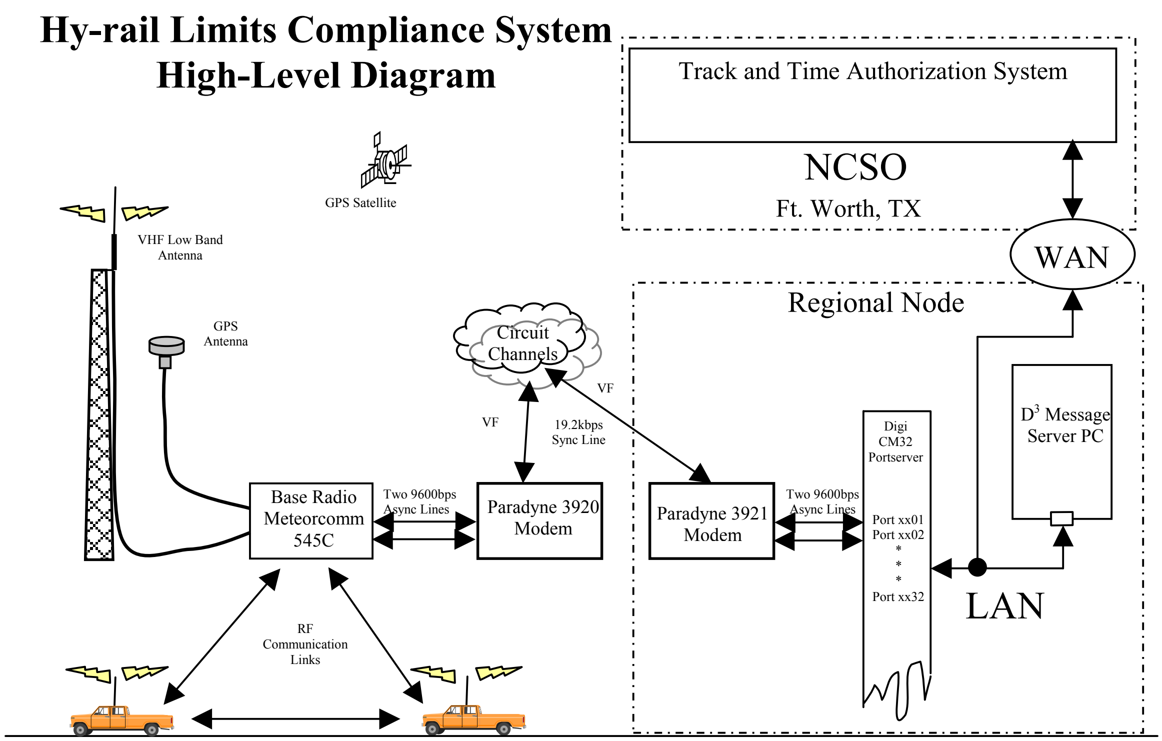
Figure 4

Safety Overlay using Low Band Radio Frequencies:

The Hy-Rail Limits Compliance Project (HLCP) has safety as its goal and is a technological approach to protecting workers on the rail. The primary reason was to implement a safety overlay system to provide additional protection of Hy-rail operators in the event they operated outside their work authority limits or their authority was inadvertently release. The bi-product of implementing this system is the creation of a robust, low-band wireless data network that would evidently extend system wide to provide connectivity to other BNSF initiatives that are currently under development. This protection includes Hy-rail vehicles operating under a track warrant in TWC territory and track and time in CTC territory. **Figure 3.1** below outlines the network design.

The Hy-rail Limits Compliance System (HLCS) is a safety overlay system that augments current legacy track authority systems by utilizing Global Positioning Satellites (GPS), wireless communications, and a Geographic Information System (GIS).

Each Hy-rail vehicle has a GPS receiver that reports its position to a base station over a wireless communications network. This geographic position report is resolved against a Railway Geographic Information Database to depict its locations as it relates to recognizable points on the railroad. This allows the Burlington Northern Santa Fe Railway to monitor the Hy-rail vehicle while it is on the track and compare its geographic position to the actual authorized working limits of the Hy-rail vehicle. HLCS equipped vehicles also have the ability to communicate with other equipped vehicles and provide a proximity alert as the vehicles approach one another. As a result, HLCS adds an extra measure of safety that alarms the vehicle occupant and the train dispatcher if the Hy-rail vehicle exceeds its authorized working limits while operating on the track. This project lays the future ground work for the BNSF to monitor its entire fleet and manage its mobile assets. The diagram on the next page provides a high level overview of the HLCS Network



Network Overview Figure 3.1

"Phase IV" in the project name indicates that this project in an extension of a previous project. "Phase I" was the pilot testing done to prove the concept of wireless position monitoring as implemented by Meteor Communication, Inc., also known as Meteorcomm. "Phase II" was the beginning of the full rollout of the system during 2001, and "Phase IV" is the continuation of that process in 2003. "Phase III" scope includes the installation of approximately 200 base stations throughout the system. These sites will be modem connected to network nodes in San Bernardino, St. Paul, Topeka, Denver, Seattle, Cicero and Ft. Worth. See Figure 3.3

Currently 700Hy-Rail vehicles are equipped with the HLCP application, with 100 more being added this year.

The HLCP is a data radio network consisting of radio equipped mobile units that communicate to network connected base stations as well as other equipped mobile units. The equipment is supplied by Meteor Communications, Inc., which is also known as Meteorcomm. The radios operate on a single low-VHF frequency of 44.58MHz, which provides good RF penetration and outdoor coverage for the power used. The Meteorcomm proprietary data protocol provides efficient data operation and throughput that approaches its 9600bps-modulation speed on a single half-duplexed RF channel.

The Hy-Rail Limits Compliance System is integrated with the existing TWC and CTC applications/servers at the Network Control Center in Ft.Worth. Spherical position reports (Lat/Lon) from Hy-rail vehicle are resolved from a GPS server to a milepost and subdivision location. This position is compared with the limits authority generated from the train control systems (TWC/CTC). These position reports generate acknowledgements to the vehicle and along with warning alarms if exceptions exist. Each mobile Hy-Rail radio is equipped with a GPS receiver. The radio is programmed to transmit its lat/long position information at predefined intervals. Once the Hy-Rail is issued track authorization, the Limits Compliance application monitors the positioning information being transmitted from the Hy-Rail radio and responds with acknowledgement that the radio is in communication with the application. These acknowledgements are accepted as showing connectivity with the controlling application and will light an LED on the Hy-Rail's Vehicle in contact with the monitoring Limits compliance application.

The Limits compliance application continues monitoring the positioning messages of the Hy-Rail vehicle until the authorization to be on the track is terminated. During the time the authorization is active, should the position report of the Hy-Rail vehicle indicate that it has proceeded to within one mile of the end of its limits and/or beyond the limits of the authorization, an alarm message is sent to the Hy-Rail vehicle. The system alerts the Hy-rail operator by means of a Visual Display Unit (VDU). This unit has visual and audio alerts that warn him when he is within 1 mile of the end of his limits and another alert when he has exceeded his limits. Figure 3.2

Another feature of HLCP is that of proximity warning. Since the Meteorcomm radios operate in a half-duplex fashion on the same frequency, mobile units are able to communicate with each other as well as to the base stations. This ability is used to create a proximity-warning function in the HLCP. Should two mobile units, equipped with the Meteorcomm radios, approach and encroach upon each other's defined "perimeter", an alert will be made available to each mobile operator to indicate that there is another mobile in their vicinity. Other features will be developed as the system matures.

FIGURE 3.2

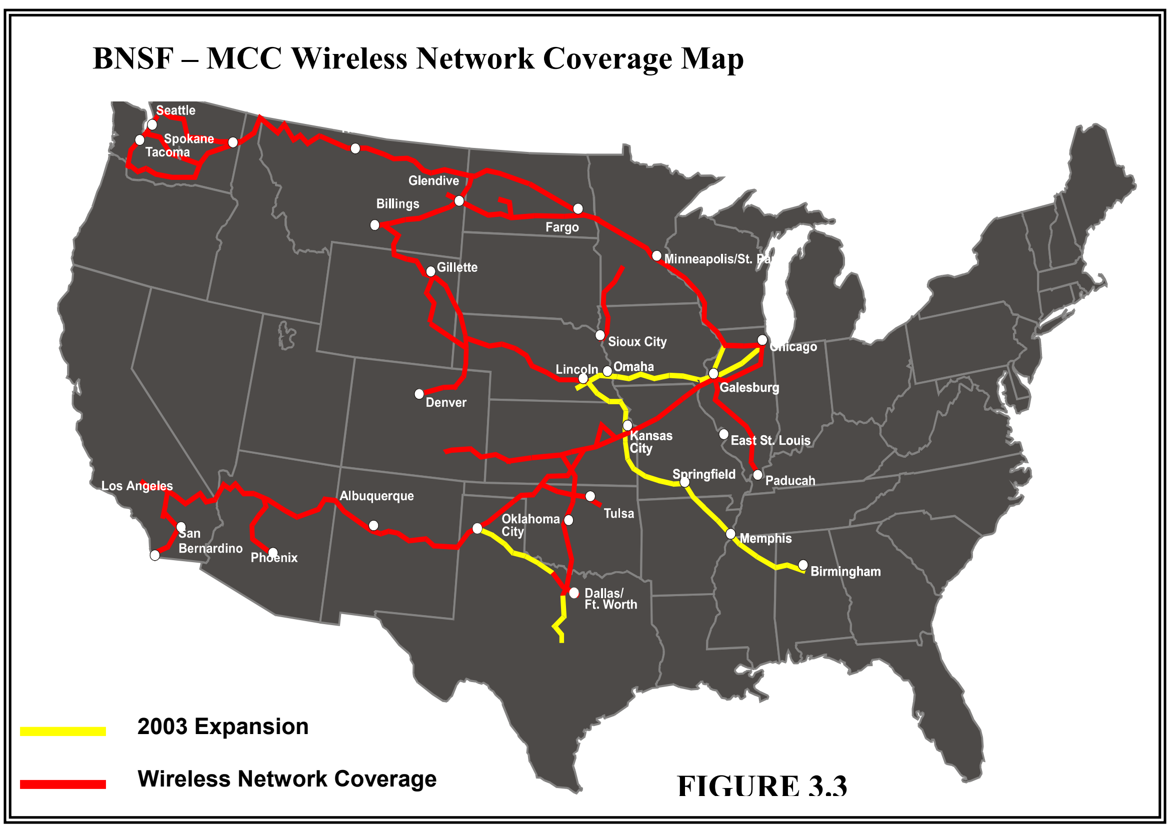


FIGURE 3.3

What are we trying to stop?