Application Note

Intel Netstructure® WiMax Baseband Card

A Solar-Powered WiMAX Base Station Solution

WiMAX can be used to help deploy broadband networks in areas with little or no access to electric power, and for many scenarios, a solar-powered WiMAX base station can provide a particularly convenient and necessary solution.

In remote locations, for example, electricity is often expensive or not available, due to lack of infrastructure. Generators can be used, but they are becoming more expensive to operate due to increasing oil prices. Likewise, disaster recovery operations are often conducted where electric power is unavailable from the grid, and WiMAX has already proven valuable in several recovery missions. Finally, solar power provides a readily available, inexpensive and environmentally friendly power source.

This applicaton note presents a feasibility study on using solar power to operate a WiMAX base station, utilizing the Intel NetStructure® WiMAX Baseband Card. It describes operational requirements and power consumption, battery and solar panel options, and investment payoff.

Target Configuration

The target configuration is a single-sector WiMAX base station. Primary components are the Intel NetStructure WiMAX Baseband Card, a MicroTCA* chassis and a remote radio head. The baseband card implements the IEEE 802.16 standard and can be programmed to operate either in 802.16-2004 mode for fixed wireless access or in 802.16e mode for mobile access (with software upgrade). The baseband card is implemented on a full-height, double-width Advanced Mezzanine Card* (AdvancedMC*) compliant with the PICMG* standard. The remote radio head consists of an omni-directional broadband antenna and RF circuitry. It can transmit in single-input/single-output (SISO) mode where a single data stream is transferred between the transmitter and the receiver, or in multiple-input/multiple-output (MIMO) mode where multiple data streams are transmitted concurrently.

The solar-powered system consists of solar panel modules, battery array and charger controller. The battery array powers the base station while the charger controller regulates power to the base station and controls charging of the battery. Solar panels provide power to charge the battery.

Operational Requirements and Power Consumption

Because a solar-powered base station is projected to operate in a remote environment, one can assume it cannot be accessed quickly and should therefore have ample backup power. The battery array has sufficient power reserve to sustain the base station for three to four days if the recharging capability is weak or non-existent. Operational requirements of the base station are shown in Table 1.

Table 1 – Operating Requirements

Battery backup capability (hours of operation with no recharging source)	3-4 days
Daily recharge time (hours of sunlight needed to fully recharge)	4-5 hours
Overcast weather operating capability (when no direct sunlight is available)	6-8 days

Typically, transmission consumes more power than reception, and the power required during transmission varies, depending on the distance of the destination station and interference conditions. The WiMAX standard supports transmission power control schemes to optimize the network throughput based on the link conditions. Typical operating power levels of the base station are shown in Table 2.

Table 2 – Operating Power Levels

	Payload	Typical Power Draw	Peak Power Draw
Baseband card	12 V	30 W	60 W
MicroTCA* chassis	48 V	30 W	40 W
Radio head	48 V	50 W (SISO)	85 W (MIMO)
Total	N/A	110 W	185 W

Using a 48 V battery array, peak current drawn is 3.86 amps, as shown in Table 3. To compute daily power consumption, the base station is assumed to consume power equivalent to a 75% duty cycle at peak power consumption. This corresponds to a daily consumption of 69.48 amp-hours, when multiplied by 1.2 as a safeguard factor to account for a slow loss of capacity over the lifetime of the battery. To recharge the battery array with an average daily recharge time of 4.5 hours, the solar panel modules should provide a current of 18.53 amps.

Table 3 – Daily Power Consumption

Peak drawn current	3.86 amps
Duty cycle	75% (18 hours daily)
Daily consumption	69.48 amp-hours with a loss factor of 1.2
Daily recharge time	4.5 hours
Solar panel current	18.53 amps

Battery

A deep-cycle battery is typically used in solar-powered systems. Thick plates allow it to be discharged deeply many times with minimal loss of capacity, providing a small current which lasts a long time, even though the total surface of the plates is not maximized. An alternative is an automobile battery made of thin plates, providing a high current for a short duration. It should not, however, be discharged deeply.

There is a wide choice of deep-cycle batteries on the market that vary according to capacity, weight, build type and form factor. The choice for this target configuration is the industrial lead-acid, deep-cycle Rolls Series 5000* 12 CS 11PS battery, designed for solar-powered systems (specs in Table 4). The 100-hour rate of this battery provides a capacity of 503 amp-hours and the 72-hour rate provides a capacity of 475 amp-hours. Four units of this battery are required. It is capable of providing three to four days of backup time while still meeting the current required by the base station.

Table 4 – Battery: Rolls Series 5000* 12 CS 11PS

Capacity	c = 503 amp-hours (100-hour rate at 5.03 amps) c = 475 amp-hours (72-hour rate at 6.59 amps)
Voltage	12 volts
Dimensions	22" (L) x 11.25" (W) x 18.25" (H); (55.9 cm x 28.6 cm x 46.4 cm)
Weight	272 lbs (124 kg)
Warranty	10 years
Lifetime	3300 cycles – Average life expectancy: 15 years

Solar Panel Options

Solar panel technology is still relatively new and is expected to grow continuously over the next decade. Current applications vary from small systems installed on houses to large systems powering communication equipment in remote environments. A wide range of photovoltaic solar panels made up of silicon nitride crystalline is available in the market with varying power output, peak current and efficiency. In this application note, two panels are considered, as shown in Table 5: the SHARP ND-200U1* module and BP Solar SX 170B* solar panel.

Table 5 – Solar Panel Options

SHARP ND-200U1*

Peak power	200 W
Dimensions	64.6" (L) x 39.1" (W) x 1.8" (H); (164 cm x 99.4 cm x 4.6 cm)
Weight	46.3 lbs (21 kg)
Limited warranty	25 years
Requirement	8 units – Total area: 140.36 ft^2 (13.04 m^2) Total weight: 370.4 lbs (168 kg)

BP Solar SX 170B*

Peak power	170 W
Dimensions	62.8" (L) x 31.1" (W) x 1.97" (H); (159 cm x 79 cm x 5 cm)
Weight	33.1 lbs (15 kg)
Limited warranty	25 years
Requirement	10 units – Total area: 135.18 ft^2 (12.56 m^2) Total weight: 331 lbs (150 kg)

As a safeguard measure, effective peak current is determined by multiplying the peak current by a factor of 0.8 to account for inefficiencies in transporting the solar power to the battery array. To provide a sufficient charging current of 18.53 amps, four SHARP modules or five BP Solar panels are required in parallel connection. Because the battery array is 48 volts, two panels are required in series for both module types. As a result, a total of eight SHARP modules or ten BP Solar modules are required (see Table 6).

Table 6 – Number of Panels Required

	SHARP ND-200U1*	BP Solar SX 170B*
Nominal voltage	24 volts	24 volts
Peak current of module	7.02 amps	4.80 amps
Effective peak current (Safeguard factor: 0.8)	5.62 amps	3.84 amps
No. of panels in parallel	4	5
No. of panels in series	2	2
Total number of panels	8	10

Investment Payoff

Cost estimates, shown in Table 7, are based on 2006 market prices which are expected to decline gradually in the future. Cost of the system includes solar panels, battery array and charger controller.

Table 7 – Total System Cost

	Based on SHARP ND-200U1*	Based on BP Solar SX 170B*
Solar modules	$7,448 ($931 x 8)	$7,850 ($785 x 10)
Battery (Rolls Series 5000* 12 CS 11PS)	$2,532 ($633 x 4)	
Charger controller	$150	
Estimated total cost	$10,130	$10,532

Investment payoff depends on the usage scenario and cost of an alternative power supply. There may be financial incentives when the alternative power option is expensive, and environmental incentives in environmentally sensitive areas when operators choose solar power over diesel generators.

The US Department of Energy Information Administration reports that the average price of electricity in the continental US varies from five to 16 cents per kWh. Prices vary, depending on demand, and are usually more expensive during summer. The price is also more expensive in Alaska where it reaches 69 cents and in Hawaii where it reaches 27 cents (http://www.eia.doe.gov/cneaf/electricity/esr/esr_sum.html).

In remote sites where there is no grid electricity, the cost of a diesel generator can be as high as 40 cents per kWh, including the cost of fuel delivery to the site. In some cases, an electric generator is transported to a repair site, which also adds to the cost.

Another option is to request an extension to grid electricity, but this is typically expensive. The cost includes installing lines and transformers in addition to other charges. For example, in New Jersey it costs $12,000 to install a 1000-ft extension line from the electric grid. The cost-per-foot declines with higher distances but is close to $24,000 for a 2000-ft extension.

Table 8 shows the investment payoff time of a solar-powered system based on annual energy production of 1,419.12 kWh. Payoff time is expected to decline steadily as the price of solar modules decreases and the cost of fuel increases. With a lifetime of 25 years for the solar panels and 15 years for the battery array, these systems can generate electricity at a cost of 33 cents per kWh.

Table 8 – Investment Payoff

Comparative Price per kWh	33 cents	40 cents	50 cents
Yearly base station consumption	1,419.12 kWh (3,888 watt-hours/day x365 days)		
Yearly cost	$468.30	$568	$710
Time to payoff (SHARP)	21.63 years	17.83 years	14.26 years
Time to payoff (BP Solar)	22.49 years	18.54 years	14.84 years

Hybrid Power Solutions

Solar-powered systems provide a modular solution and can be used alongside other power sources. A hybrid power system can be customized depending on the deployment scenario and can be economically competitive.

If the power load has high variations on a daily basis, it is inefficient to run a diesel generator exclusively, since the capacity of the generator must be high to match the peak draw. However, when the equipment consumes less power, the efficiency of the diesel generator increases. For this scenario, a hybrid system can be configured so that the diesel generator handles the baseline power consumption, and the solar-powered subsystem manages the balance.

Another example is Etisalat, the national telecommunications operator of the United Arab Emirates, which uses a hybrid system for a portion of its cellular network. Originally, the operator was running a diesel generator at a site with high daytime humidity, rendering the generator inefficient. A hybrid solar/diesel system, built by Maryland-based Integrated Power Corporation, now powers the equipment by solar power during daylight hours and by diesel generator at night. The system is expected to reduce fuel consumption by 75%.

Conclusion

Intel and its ecosystem vendors are making it both economically and technologically feasible to operate a base station powered solely on solar technology. Specifically, the Intel NetStructure WiMAX Baseband Card, along with advances in radio technology, enables operators to deploy and operate a fully functioning solar-powered base station. While the capital costs may initially appear high, these costs are, in fact, comparable if not lower than electric grid extension or fossil fuel generation alternatives. In addition, solar power may be the only source of power available in times of disaster. Consequently, the solar-powered alternative offers great potential to improve power efficiency and availability, and lower operating expenses while supplying power to remote locations and disaster recovery operations.

Resources

Batteries

- Rolls Batteries http://www.rollsbattery.com/

Solar panel modules and complete power systems

- BP Solar http://www.bp.com/modularhome.do?categoryId=4260
- SHARP Solar http://solar.sharpusa.com/
- SunWize solar products http://www.sunwize.com/
- Solar panels wholesale http://www.wholesalesolar.com/solar-panels.html

Stand-alone solar-powered systems

- Solar electric supply http://www.solarelectricsupply.com/systems/greenpower/stand-alone.html
- Sierra solar http://www.sierrasolar.com/prod_store/packaged_sys.html

Custom design of solar-powered systems

- Integrated Power Corporation http://www.ipowercorp.com/index.htm
- SCHOTT Solar http://www.us.schott.com/photovoltaic/english/

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