Lopoco Next Generation Ultra-Efficient Datacenter

### System Overview

The need to make data centers more energy efficient has been identified for several years now. Until now, the focus of many innovations and advancements has been in the areas of cooling, backup power generation and non IT electrical equipment (ie., lights, human inhabitant needs, etc.).

This patent focuses on the one area that remains largely untouched, and that is the efficiency of the data center IT equipment, which includes primarily computer servers, network switching appliances, and computer storage appliances and related equipment.

The efficiency of data center IT equipment is particularly bad primarily because of one simple fact: the provisioning of IT servers and equipment falls to those who don't know what application will be running on them, and, even if they have some advance information about that, they can't know what will be running on the servers in the future. Trying to coordinate between the two disparate responsibilities of provisioning and application selection has been, and is being, attempted on some level by many companies, but it typically a very slow process which neither group is all that interested in, and as such often fails. The result is a that the data center is almost entirely provisioned with a one-size-fits-all (OSFA) server configuration, which can't be designed to any successful level of efficiency. Even if some provisioning is done of a server configuration specifically matched to an application category, when that application is retired which sometimes might be as little as six months later, there exists no criteria by which those servers can be re-purposed and so are replaced with OSFA servers.

This patent description will cover a system by which an ultra-efficient data center can be accomplished.

1. Design for attaining efficiency from IT equipment
   1. In order to create a datacenter that uses its IT equipment efficiently, it must have 3 things:
      1. Servers and storage equipment that can operate efficiently, grouped into classes based on application workload footprint
      2. The dynamic and/or manual ability to match applications with the server configuration/model that is best suited for it on an acceptable efficiency/performance scale, and the ability to seamlessly migrate or run those applications on the equipment selectively suited for it
      3. Data center cooling zones based on the TDP of the server classes housed within each zone – with right-sized HVAC (cooling) provisioned separately for each zone. Zones will be physically separated enough so that the HVAC resources provisioned for each zone area will not be burdened with cooling duties for other zones/areas.
   2. Therefore data centers will be divided into separate server {workload,cooling} or “application class” zones, with the HVAC requirements accurately known for each zone, so cooling equipment requirements will be well understood for each zone and can be very precisely provisioned, allowing for great cost savings over traditional designs, where the cooling is provisioned based on the maximum power available to the entire data center, rather than the actual cooling requirements of the IT equipment. These zones may or may not be separate buildings or structures, so in fact a data center may be comprised of only one zone.
   3. Use of ultra-efficient servers with accurately specified TDP will substantially decrease the amount of cooling required vs. the throughput of the servers, again decreasing costs substantially.
   4. In the same way as for cooling, the same may be done for battery backup power resources (UPS), generator backup power resources, and power distribution equipment such as internal data center power lines and cords, and power distribution units (PDU). We can aggregate all these into one group labeled “power infrastructure resources”. Again allowing for accurate right-sizing of power infrastructure resources results in very large cost and power consumption reductions over a conventional data center.
   5. Use of ultra-efficient servers will allow for substantial increase in overall throughput of a data center v. the data center's total power budget, substantially increasing the value of a data center with a specific power budget.
2. Application Control and Migration
   1. Proprietary application management and control software and hardware will be utilized to identify and analyze applications with respect to their computing resource needs, and migrate or launch applications to the server category best suited to handle the application efficiently. This section covers the design and implementation specifics of that sub-system.
   2. Design specifics of app monitoring/migrating/controlling system  
      The application monitoring, migrating and controlling functionality is a confluence of software and hardware. The hardware involved is typical power and environment monitoring hardware where data on power consumption and heat can be constantly monitored and gathered. This data, along with software monitoring metrics gathered from the servers themselves on the resource usage patterns of running applications, is used as input to the application migration software.
      1. Application migration software  
         This part of the system utilizes the data from the sensors and application monitoring metrics to migrate applications from one data center class to another, or take no action if an application is continuing to amount of resources intended for the application class data center sub-module where it currently is running.
      2. Processor resource usage  
         If an application is consistently using 80% or greater of the available CPU resources in its current sub-module class, and there is a sub-module class with a higher performance processor, then the application will be migrated to that class. If an application consistently is using no more than 10% of the available CPU resources in its current sub-module class, and there is a sub-module class with a lower performance processor, then it will be migrated to that class.
      3. Network resource usage  
         If an application is consistently using 100% of the available networking resources in its sub-module class, and there is a sub-module class with higher throughput networking hardware, then the application will be moved to that sub-module class. If an application consistently is using less than 10% of the available network bandwidth in its sub-module class, and there is a sub-module class with lower speed networking, then it will be migrated to that sub-module class.
      4. Storage resource usage  
         Since all storage in the data center will be available to all the servers in the data center, the amount of storage required by an application will have no bearing on which sub-module class it is executing in. If an application consistently experiencing high I/O wait times for disk I/O operations, and there is a sub-module class with higher performance storage hardware, then the sub-module will be migrated to that sub-module class. For this algorithm, high I/O wait times are when the CPU time is 90% or more disk I/O wait time.
      5. The migration decision structure is weighted with CPU the highest priority, then Network, followed by Storage.
      6. There are two methods of application migration.
         1. Start/Stop  
            The application is merely stopped in one place, and restarted in another, but not necessarily in that order. An example would be a web service application, which can be started in the destination sub-module class, and once started, stopped in the origin sub-module class.
         2. Virtual Machine Migration  
            Most virtual machine frameworks these days include the ability to migrate an application from one server to another. Many large data centers now employ an application container framework. Such frameworks can be heavily employed to migrate services and application containers from one group of servers in a sub-module class to another.
3. Ultra-Efficient Server Design
   1. Low Power Server, Server Systems and Design Methodology Thereof
   2. Technical Field
   3. This invention relates to the design methods and the design of various components in the creation of ultra-efficient computer servers, storage systems, and other Information Technology devices such as network or storage switches.
   4. Background Art
   5. Currently, the design of high-volume standard computational servers tends to follow one path – high performance. This invention concerns the creation of a new path: energy efficiency.
   6. Designing a server for energy efficiency generally relates to the process and methods of reducing the average power consumed by a server while still providing requisite performance and functionality as similar servers which are not energy-efficient. Such power efficienct servers are currently designed by selecting non-standard off-the-shelf components from vendors offering lower-power-components. Additionally, major components such as printed circuit boards, fans and power supplies can be specifically designed with the intention to maximize efficiencies in: electrical power distribution and conduction; cooling; and emissions in auditory and electromagnetic categories, without sacrificing needed levels of system performance.
   7. Almost nothing, apart from lip service, is done today by conventional server manufacturers to create energy efficient servers, unless you count minor attempts such as “shared fans”, which, while in some cases can be slightly (2%?) better than conventional servers, is actually not the most efficient way to go. In other use cases, shared fans can be less efficient compared to similar conventional servers. As such, this does not provide sufficient gains in efficiency to really be considered as an efficient design or as a valuable proposition in the market place. Completely missing from the market place is the ability to know how much power a server consumes, and therefore be able to compare that power consumption to other servers, server racks, and entire datacenters. This inability to compare and rate power consumption, both on a server-versus-server basis and on a server-versus-application-load basis means that no conventional server manufacturer has the ability to know, and therefore to claim, that their products are efficient. Rather, the servers produced under this standard methodology are generally specified by the capacity of the power supply included and do not yield the significant power savings possible through the use of this art.
   8. In order to design for maximum energy efficiency, all components of the server must be considered and measured for their contribution to power consumption and power dissipation (in the case of fans and air flow controllers), as well as the relationship between all those components in regard to the TDP of the server. Additionally, the server design must be must have a repeatable, deterministic methodology for measuring maximum power consumed. For this embodiment, both Idle Power Consumption (IPC) and Total Design Power (TDP), which represents the maximum power a server will consume under full computational load, will be considered as the measure of energy consumption. IPC represents the power consumed by the device when it is powered up and ready, but has negligible computational load (idle). TDP is important to server customers because it allows a well-engineered design of the power distribution infrastructure and the HVAC provisioning in order to have a smooth running data center and high reliability and availability of the services the IT equipment is intended to provide. IPC is important because most servers spend 80-90% of their existence in the idle state. Accurate measurements of the TDP of a server are currently unavailable on standard servers. Anecdotal TDP measurements for a server are sometimes available from third parties, however these are always very innacurate (sometimes as much as 50% too low) and only applicable to the particular configuration tested by the third party. This last part is very important because conventional servers can have widely varying arrays of possible components, resulting in a configuration matrix for just one model of server that numbers in the tens of thousands.  
      All servers will require varying amounts of power depending on the instantaneous load on the computational components as well as on the power supply and cooling system. As the computational load increases, so does the power consumed by the server. Once the components are operating at their maximum capacity, all electrical components in the server will be theoretically operating at their maximum and TDP should then be measured. Figure 1/conventional shows the TDP curve for servers designed under a conventional methodology, and Figure 1/lopoco under the art of this invention. Comparing the two curves, it is evident that the power consumption is substantially lower for servers produced under the art of this invention, yet the server throughput stays similar.
   9. Designing a highly efficient server requires power consumption to be minimized while maintaining requisite performance throughput. While obtaining a reasonably accurate IPC figure for a server is relatively straightforward, doing so for TDP is quite difficult. An embodiment of this invention utilizes a testing process, methodology and algorithm to most accurately determine the TDP rating of a computer server. This design methodology requires the Special Copyrighted Software Program (SWTDP) to fully exercise all computational components to create as close to 100% loaded conditions as practicable at which point power consumption is measured, thus yielding TDP for a given design. Designs are iterated using the flowchart shown in Fig 3 to select the most energy efficient components and configurations. Power reductions in the computational components and motherboards have a feedback effect on secondary components such as fans and power supplies. As the server becomes more and more power efficient, less power is dissipated requiring less powerful cooling components and lower total-power-output power supplies which further reduce the TDP of the server. By using SWTDP to fully exercise the system components, a minimized TDP is specified as the maximum power the server will consume under virtually any condition. This TDP can be used as a design parameter of systems consisting of 100’s or 1000’s of servers configured in racks in commercial applications such as businesses and data centers. By utilizing a significantly lower TDP than conventional servers, server racks and data centers can be designed with lower energy consumption and lower cooling requirements. Since powering and cooling of collections of servers also consumes its own power, these datacenter subsystems also become more energy efficient. Thus, the ability to design a server to a significantly lower, ultra-efficient power consumption causes a ripple effect and virtuous circle of power reduction and energy efficiency gain.   
      [Andy How do we weave in the idea of equivalent performance? – “…. while maintaining overall server performance design goals” “…without sacrificing performance” – is this the overall thinking? Where to capture? I think I did by use of the words `requisite' and `required'. We could also say `required application performance'.
   10. Designing the non-computational components for higher efficiency becomes possible as the power of computational components is reduced. The focus of the designs are to improve cooling efficiency by more effectively controlling air flow within the server and having the cooling system dissipate less power. These designs fall into the following categories: A) efficient motherboard design; B) ultra-efficient power supply components C) greater fan efficiency; D) utilization of airflow controlling devices to smooth and direct cooling airflow inside a server; E) use of 42mm system fans; F) fans with variable speed that can also be shut off; G) BIOS/boot up/ACPI code; H) Server case design for efficient airflow, including air intake and exhaust grill areas.
       1. Computer server motherboard design elements for increasing overall power efficiency
          1. Use of 5 volt fans instead of 12 volt fans  
             5-Volt fan headers, allowing the use of 5V fans which typically can move equivalent amounts of air while using equivalent amperages in slower speed fans, but at 5 volts instead of 12 volts, allowing a significant reduction in wattage over traditional 12 volts fans. In efficient servers that don't need high speed and/or high pressure cooling fans.
          2. Onboard components and component connector placement/alignment  
             Memory, cable connectors and other components that are wider in one aspect than another, are mounted with the thinner aspect in line with the direction of cooling air flowing though the computer, thus increasing cooling efficiency. This is shown in low detail in Fig. 4a.
          3. I/O device connector port placement  
             Conventional designs located these headers on the left side of the board, which is usually in the direct path of the air flow cooling the CPU. This new design locates the rear I/O ports, and any other vertical components, on the opposite side of the motherboard from the CPU or CPUs to prevent them from obstructing the cooling air flow. This substantially improves air flow over the motherboard (and therefore through the computer case) of cooling air propelled by cooling fans. With the rear I/O headers, ports and other large components moved out of the way, the cooling air can flow across the CPU and other hotter parts, and exit the case substantially easier, allowing the use of less powerful fans to cool the components of the computer server, which in turn reduces the amount of energy consumed overall by the computer server. This applies to the I/O ports, but also to other tall components that could hinder air flow. Also shown in Fig. 4 A.
          4. Use of highly efficient components  
             Use of components, especially I/O controllers, that are designed for the high efficiency requirements of mobile computing. Including, but not limited to: network controllers and the associated PHY; CPUs; fan controllers; disk controllers and associated integrated circuit devices; video controllers (if any); USB controllers; and keyboard/mouse controllers.  
               
             [Andy – we think we have the case where you can describe a redesign of motherboards for low power and high efficiency that may not have been capture above. If so, please add.] I think we can make much more of this particular item, but perhaps that's best done in a full application that pertains to efficient motherboard designs. Motherboards with network controllers designed for mobile (laptop) applications; low power PHYs as used in mobile applications; use of mobile (notebook/laptop) processors with greater levels of frequency scaling to further reduce IDC. Add to that a BIOS that is designed in the last 20 years that will give a 50-60% reduction in power consumption during POST.
       2. Ultra-efficient power supply components
          1. The importance of being able to use of ultra-efficient power supplies cannot be overstated. Conventional power supplies may claim to be 80% or 90% efficient, but in fact only achieve that level of efficiency when producing greater than 200 watts of power. Even when operating at those efficiency levels, they are very wasteful and such a deficit cannot be overcome. Power supplies such as those currently utilized by Lopoco are able to operate at 80-90% efficiency while outputting only 20 watts of power, and immediately jump to 97-99% efficiency at output levels above that. Therefore we can see that a conventional server that is consuming 200 watts is wasting 40 watts *just in the power supply alone*, which means the computational and cooling components of the server are only consuming 160 watts.
       3. Fans with disappearing frame segments
          1. Fans have “disappearing” frame segments on the top and/or bottom of the fan, so that the blades come as close as possible to the top and/or bottom of the enclosure they are located in, maximizing fan blade size to the available space in the enclosure. See figure 6. This means that the external dimensions of the entire fan assembly will not be square, but in fact wider in the horizontal than in the vertical. This allows for a larger fan blade to be used in a fan that is located in an enclosure and therefore doesn't need an encompassing frame to protect the fan from foreign objects or to protect foreign objects from the spinning fan blades.
          2. Fans are often made of plastic: plastic frame and plastic blades. These fans will have soft touch plastic at least on the bottom and top of the frame, so as to damp vibrations coming from the fan, minimizing the amount of vibrations transmitted to the rest of the computer server and its components. Also, this soft touch plastic, a common material often found in car dashboards and other consumer products, will aid in holding the fans in place. For fans made of metal or other material, a thin coating of soft touch plastic, or other vibration damping material such as rubber or silicone, can be applied to the frame material to achieve the same result. See Fig. 7.
       4. Device(s) to smooth and direct cooling airflow inside a computer
          1. Small devices that can be attached to the computer motherboard to aerodynamically smooth the flow of cooling air around and/or above protuberances and blockages (I/O ports; I/O headers; electrical components such as capacitors, transistors, coils, etc.; cable attachment headers; the motherboard itself) that normally have a rectangular or other non-aerodynamic shape which blocks efficient air flow. Optimizing the air flow around such blockages allows for more efficient cooling of the computer, which allows for a reduction in the amount of fan power required.
          2. Batteries, speakers, electrical coils, capacitors and other components on the motherboard. The shape of air flow blockers inside a computer case are usually rectangular or of a rectangular cross section. This is because these blockages are most commonly the rear I/O ports attached at the back of the motherboard. But other devices or objects can also block the flow of cooling air. The motherboard itself is not aerodynamically optimized, hence one of the devices is designed specifically to direct all air flow coming from the fans above the motherboard where it can do the most good.
          3. In the case of wider blockages such as multiple I/O headers mounted side by side on the motherboard, the devices are intended to be used in groups. The size of the devices would be chosen to match the height and width of the blockage(s).
          4. The device(s) will have various shapes, including:  
             Basic vertical wedge shape, as seen in Fig. 8 (side view sketch) and Fig. 10. We need more drawings here. I did some hand drawn, but we need some that are better than that. This shape is designed to transition air flow over the top of the blockage.
          5. Basic blended vertical and horizontal wedge, used to transition air flow over and around a single blockage. This shape would more or less come to a point at the leading edge, resembling a cone cut in half from top to bottom and then laid flat, with the pointed end pointed towards the air source, most likely a fan or fans. The tail end of the device would not necessarily be rounded like a simple cone, but be a match for the vertical cross section of the blockage itself, and that shape gradually shrinking towards the leading end of the device.
          6. Devices that are essentially device shape #2 cut into right and left halves. These are to be used in conjunction with device shape #1 to create a complete air flow transition around larger blockages possibly consisting of multiple I/O headers mounted side by side or nearly so.
          7. Rounded versions of the above described shapes.
          8. The devices are made of a very smooth, hard material, most likely plastic for cost and light weight, facilitating good air flow.
          9. The devices may have a thin, soft layer on the motherboard side that is coated with reusable adhesive. The soft layer is malleable and does not rebound, allowing the device to be pressed down over small surface mount components that may be on the motherboard in front of the blockage(s). Not applicable when device shapes are built in to components or headers.
          10. Designs or shapes described above, but integrated into the external case of the I/O header or component itself.
       5. 42mm system fans for use inside a computer server case
          1. Computer server cases that are 1U tall (1.7 inches or 43mm) suffer from lack of efficient cooling fan solutions, because the internal case volume is relatively small. Fans that are situated inside such cases are referred to as case fans. This is a design for 42mm case fans specifically for optimizing efficiency of cooling.
          2. Current 1U case fans are 40mm square, and anywhere from 5mm to 25mm deep, or deeper. This fan design specifies 42mm fans, thereby leaving no amount of internal space empty.
          3. Fans have “disappearing” frame segments on the top of the fan, so that the blades come as close as possible to the top (or bottom) of the case, maximizing available space. This means, among other things, that the fans can reasonably only be installed in the case one of two ways: that is, with the open frame sides facing the top and bottom of the case. It also means the external dimensions of the fans may not be square, but in fact wider in the horizontal than in the vertical.
          4. Plastic frame and plastic blades. Fans are generally made of plastic. These fans will have soft touch plastic at least on the bottom and top of the frame, so as to damp vibrations coming from the fan, minimizing the amount of vibrations transmitted to the rest of the computer server case and its components. Also, this soft touch plastic, a common material often found in car dashboards and other consumer products, will aid in holding the fans in place.
       6. Variable speed fans which can be completely powered down  
          Computer system fans that can, besides varying their RPM and thus varying the amount of power they draw and the amount of air they move, can completely stop the fan motor, essentially drawing no power. Either through a communication signal via an interface, or merely by setting the fan supply voltage to zero, the fan will stop. The fan can start again when signaled to do so or when supply voltage is raised to nominal levels. This will significantly reduce the amount of power consumed by a computer when it is in idle or low power mode, and passive convection cooling is sufficient to cool the system or parts of the system.
       7. BIOS/Boot up code for ultra-efficient server
          1. Boot up and self-test ROM or NVRAM code (herein called BIOS or POST code) that greatly decreases the amount of power consumed during the boot and self test phase.  
             Current BIOS code in PC derived computer systems including servers utilizes a continuous loop design meant to refresh the video display. The use of directly connected video displays is a long since deprecated practice for servers. Our boot up code would dispense with the continuous loop video refresh code altogether and utilize an interrupt driven design, thereby drastically reducing power consumption during boot up, system test, and interactive operations.
          2. Fan management code capable of turning one or more of the cooling fans off, or put another way, RPM of zero, when fan operation isn't required to cool the system.
          3. Significantly increase the effectiveness of thermal management code, especially in the particular area of fan control, in the BIOS to help reduce power consumption of the system during operation.
       8. Computer server case and motherboard design elements for more efficient air flow though the case
          1. This description covers new computer server motherboard design elements, and matching case design elements, to facilitate less restricted air flow through the case, thus increasing cooling efficiency of the running computer server.
          2. Fig. 8 shows the motherboard design with the rear I/O ports located to the left and right sides of the rear edge of the motherboard. Traditionally these have been placed according to some standards which often find them directly in the path of air flow over the server's hottest components, such as the processor and power transisters. Relocating them in this fashion allows substantially less restricted airflow through the case of cooling air moved by internal cooling fans. With the rear I/O headers and ports moved out of the way of the bulk of this air flow, the cooling air can exit the case substantially easier, allowing the use of less powerful fans to cool the internal components of the computer server, which in turn reduces the amount of energy consumed overall by the computer server.
       9. Air intake and exhaust grill design
          1. Currently, all computer server cases consist of a grill pattern stamped or cut out of sheet metal, usually aluminum. The thickness of the grill hatching is usually 2 — 2.5mm. Sometimes it is as thin as 1mm, but usually in a higher density, thus negating the thinness of the hatching in terms of easing air flow. The grill element of these cases is designed this way because these server cases use the grill metal as structural elements of the case. However, the thickness of the hatching in these grill designs severely retards air flow, badly affecting cooling efficiency.
          2. Our design is to have separate structural elements akin to pillars in a building, that are outside of the critical cooling air flow, and to utilize non-structural, non-load bearing grill material that has very thin hatching, in the 0.1mm or less thickness range, in the areas of the case that in the critical path for intake and exhaust of cooling air, thereby substantially reducing the power needed to move cooling air through the case. This will decrease the amount of air that cooling fans have to push or pull through the system, thus reducing the overall amount of power consumed by the system.

The design of highly efficient servers facilitates the design of future highly-efficient data centers. Server design methodology utilizing the described TDP testing the procedure can be used to create servers and/or other computer related appliances (such as: computer storage machines; communication or storage networking machinery) with accurately specifiable power consumption profiles. These can then be used to design the next generation power-optimized data centers using application centric data center modules. These modules can include server designs as well as highly efficient network routers and other devices which were are designed utilizing a similar TDP methodology. See Figure 4b.  
  
The ultra-efficient design methodology also facilitates designing servers for special application computing needs. Some examples: big data processing; image/video/audio search; speech recognition. Servers maybe optimized for use of general purpose processors, or GPUs, FPGAs, and ASICs. The ability to deploy allows for the Design of Next Generation All Purpose Data Center (NGAPD) utilizing application-centric data center sub-modules comprised of ultra-efficient servers designed for that application category along with a method for analyzing existing/running applications and migrating them to the appropriate submodule of the NGAPD intended to most efficiently run them.  
  
The ultra-efficient design methodology also facilitates a blade server design implementing variable load power supplies, preserving high efficiency levels regardless of load (population level of blade chassis).

1. Efficiency and Total Design Power measuring technology
   1. In order to be able to achieve I.a and III, an accurate and repeatable method of determining the power consumption footprint of a server must be utilized. For III, it is utilized extensively in the research, engineering, design, and verification and verification phases. For I.a, the accurate and reliable power consumption of specification for IT equipment, especially servers and compute appliances such as computer storage and networking equipment, is crucial to the process. In this section, we will describe the uniquely accurate test measuring software and methodology created by Lopoco to get an accurate and reliable specification for Idle and TDP for a server.

**Server TDP Software Design**

Summary: the software program attempts to utilize all the compute and I/O resources of a server at the same time, thereby causing all subsystems of the server to be using the maximum power that they could ever consume.

Overview: modern computer hardware, both integrated and discreet circuits (often called chips and components, respectively), have some ability to curtail power consumption when some or all of their capabilities are not being used. For example, a processor may shut down a floating point computation unit when there are no floating point computations to be done, or a network controller might shut down parts of its logic during periods of little or no network traffic, etc. These periods of shutdown or power down may be extremely short, possibly measured in nanoseconds or microseconds. If there is no carrier signal detected on an ethernet port, the ethernet PHY may power down for 950 microseconds and power up for 50 microseconds every millisecond to check if a cable has been connected and a possible link can be established, thus reducing power consumption by 95% if a network port is unused. The TDP software is designed to specifically defeat these power saving techniques as much as possible in order to make a server consume the most amount of power a server possibly can. The method is to run the software on a target server, and with help from one or more helper servers to send and receive network traffic, and measure the power consumption of the server during the time the application is running. Power consumption measurement tools have the ability to record the maximum instantaneous power consumption during an arbitrary time period, and these numbers (watts, PF, amps and volts) are stored and recorded in a database, so that the observed TDP for each and every server is known.

The detailed algorithms for exercising each subsystem of a server are split out by each subsystem in the list below.

* + 1. General Purpose Processor

Today's modern general purpose processors have multiple CPU cores, large memory caches, TLBs, memory controllers, data buses and bus controllers, and I/O device controllers. Each CPU core has many multiple execution units and instruction pipelines. All of these are manipulated by the logic in the processor to save power when not being used. The challenge is to use software that keeps as much of the whole processor “lit up” (not able to power save). Lopoco uses encryption key generation and computation software that uses all of the floating point and specialty instruction units as possible, while simultaneously using decent amounts of memory. Z instances of this program run, where Z = (the number of logical CPU core available on the processor or processors in the system) + 2. This prevents the processor(s) from shutting down execution units, pipelines, memory controllers and other such parts to reduce power consumption. Running Z copies of the program means that a wide range of memory in the system is used, lowering the amount of power saving the memory chips and memory controllers can do. We have tested many software programs for the purpose of maximizing processor and memory usage, and while many do well at this goal, the openssl key generation program produces results that cannot be equaled or exceeded by any other available program, which means that an ordinary user running any software on the system will not be able to cause the server to consume more energy via the processor, which is the ultimate goal.

* + 1. Disks and disk I/O controllers

Similar to processors, disks and disk I/O controllers have electronics that are designed to save power dynamically based on idle time. The TDP software discovers all the disks in the system, groups them by type and model, and creates a software RAID setup for each group. A separate program loop repeatedly unarchives a large file archive onto each group of disks, causing a large number of disk writes to be performed. For all types of disks (rotating media and SSD, to name two), the write cycle consumes the most power. Expanding these archive files also two additional effects: because a decent amount of metadata reads are performed, on rotating media substantial extra head seeks are incurred, increasing power consumption; and because the archive contains many small and some large files, this causes a large backlog of pending writes to be queued up by the disk controller devices, causing them to maximize power consumption. A program loop runs in parallel for each group of disks, keeping all disks busy all the time.

* + 1. Network devices

Utilizing at least one helper server, a network connection is set up from the target server to the helper server, and simultaneous bi-directional data transfers are performed on a continuous and repeating basis. Since most “normal” network traffic consists of one machine transmitting while the other receives, network controllers can save some power consumption by powering down the unused receiver or transmitter, respectively. Therefore the TDP software is specially designed to setup bi-directional transfers to eliminate that power usage optimization. The software has a user selectable option to exercize an additional network port, and by extension an additional helper server on the other end of the network connection. This option is initially intended servers with additional higher speed network devices, for instance a 10G, 40G or 100G network device, which currently can consume considerably more power when at idle as well as when fully utilized than a conventional 100BT or 1G ethernet network interface.

* 1. TDP Testing Methodology
     1. A brief description of the testing methodology that is employed to ascertain the idle and TDP power consumption figures for a server – utilizing the TDP software.
     2. When a server is released from the production line and ready to be tested, it's power cable Is plugged into a power consumption measuring lab equipment. This test device must be both accurate and repeatable, and must give at least for reading for power consumption: watts, power factor, amps and volts. It must also have the capability to display or record the maximum numbers sensed during a certain time period. A network cable is connected to at least one of the server's network ports. All disks and devices that the unit will ship with must be on the system and must power on when the system is powered on. If the system has a video connector and/or a keyboard connector, those must be attached to suitable devices so that the power the system would utilize to operate them will be consumed. Most servers do not use a mouse, so no such device need be connected.
     3. The server must be booted, either from a non-disk medium such as a USB stick, or network booted, which means a portion of the system memory is set aside to load the operating system and runs from there. Currently a version of the Debian Linux distribution is used, which typical but not extraordinary services running but unused, such as the apache web server and mysql database server, as well as a few other sundry minor services. An IP address is obtained from a DHCP server via the network that is connected. After the system fully completes the bootup process, a suitable time is waited to allow the system to quiesce so that a reasonable idle power consumption figures may be observed and recorded.
     4. Then the TDP exercising software is run, but not before the idle power figures have been recorded, and the power meter must be set to record the maximums if such an additional setting is required on the meter to obtain the maximums, and the initial questions asked by the software are answered, and the main power exercising portion of the program begins. This portion of the program can take 15-30 minutes, roughly, depending on the performance capabilities of the server and the processor(s). When the power exercising portion of the program has completed, the maximum (TDP) power figures can be entered by hand, or, depending on the capabilities of the lab equipment, may be transmitted electronically to the operations database server for recordation. A portion of the software also inventories the server's memory, disks, network and disk controllers, and processor(s), and electronically transmits this to the operations database server as well, however this function of the software is covered in detail in a separate application document.