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- access method** The method that is used to find a file, a record, or a set of records.
- address space** The range of addresses available to a computer program.
- address translator** A functional unit that transforms virtual addresses to real addresses.
- application programming interface (API)** A standardized library of programming tools used by software developers to write applications that are compatible with a specific operating system or graphic user interface.
- asynchronous operation** An operation that occurs without a regular or predictable time relationship to a specified event, for example, the calling of an error diagnostic routine that may receive control at any time during the execution of a computer program.
- base address** An address that is used as the origin in the calculation of addresses in the execution of a computer program.
- batch processing** Pertaining to the technique of executing a set of computer programs such that each is completed before the next program of the set is started.
- Beowulf** Defines a class of clustered computing that focuses on minimizing the price-to-performance ratio of the overall system without compromising its ability to perform the computation work for which it is being built. Most Beowulf systems are implemented on Linux computers.
- binary semaphore** A semaphore that takes on only the values 0 and 1. A binary semaphore allows only one process or thread to have access to a shared critical resource at a time.
- block** (1) A collection of contiguous records that are recorded as a unit; the units are separated by interblock gaps. (2) A group of bits that are transmitted as a unit.
- busy waiting** The repeated execution of a loop of code while waiting for an event to occur.
- cache memory** A memory that is smaller and faster than main memory and that is interposed between the processor and main memory. The cache acts as a buffer for recently used memory locations.
- central processing unit (CPU)** That portion of a computer that fetches and executes instructions. It consists of an Arithmetic and Logic Unit (ALU), a control unit, and registers. Often simply referred to as a *processor*.
- chained list** A list in which data items may be dispersed but in which each item contains an identifier for locating the next item.
- client** A process that requests services by sending messages to server processes.
- cluster** A group of interconnected, whole computers working together as a unified computing resource that can create the illusion of being one machine. The term *whole computer* means a system that can run on its own, apart from the cluster.
- communications architecture** The hardware and software structure that implements the communications function.
- compaction** A technique used when memory is divided into variable-size partitions. From time to time, the operating system shifts the partitions so that they are contiguous and so that all of the free memory is together in one block. See *external fragmentation*.

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concurrent Pertaining to processes or threads that take place within a common interval of time during which they may have to alternately share common resources.

consumable resource A resource that can be created (produced) and destroyed (consumed). When a resource is acquired by a process, the resource ceases to exist. Examples of consumable resources are interrupts, signals, messages, and information in I/O buffers.

critical section In an asynchronous procedure of a computer program, a part that cannot be executed simultaneously with an associated critical section of another asynchronous procedure. See *mutual exclusion*.

database A collection of interrelated data, often with controlled redundancy, organized according to a schema to serve one or more applications; the data are stored so that they can be used by different programs without concern for the data structure or organization. A common approach is used to add new data and to modify and retrieve existing data.

deadlock (1) An impasse that occurs when multiple processes are waiting for the availability of a resource that will not become available because it is being held by another process that is in a similar wait state. (2) An impasse that occurs when multiple processes are waiting for an action by or a response from another process that is in a similar wait state.

deadlock avoidance A dynamic technique that examines each new resource request for deadlock. If the new request could lead to a deadlock, then the request is denied.

deadlock detection A technique in which requested resources are always granted when available. Periodically,

the operating system tests for deadlock.

deadlock prevention A technique that guarantees that a deadlock will not occur. Prevention is achieved by assuring that one of the necessary conditions for deadlock is not met.

demand paging The transfer of a page from secondary memory to main memory storage at the moment of need. Compare *prepaging*.

device driver An operating system module (usually in the kernel) that deals directly with a device or I/O module.

direct access The capability to obtain data from a storage device or to enter data into a storage device in a sequence independent of their relative position, by means of addresses that indicate the physical location of the data.

direct memory access (DMA) A form of I/O in which a special module, called a DMA module, controls the exchange of data between main memory and an I/O device. The processor sends a request for the transfer of a block of data to the DMA module and is interrupted only after the entire block has been transferred.

disabled interrupt A condition, usually created by the operating system, during which the processor will ignore interrupt request signals of a specified class.

disk allocation table A table that indicates which blocks on secondary storage are free and available for allocation to files.

disk cache A buffer, usually kept in main memory, that functions as a cache of disk blocks between disk memory and the rest of main memory.

dispatch To allocate time on a processor to jobs or tasks that are ready for execution.

distributed operating system A common operating system shared by a network of computers. The distributed operating system provides support for inter-

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process communication, process migration, mutual exclusion, and the prevention or detection of deadlock.

dynamic relocation A process that assigns new absolute addresses to a computer program during execution so that the program may be executed from a different area of main storage.

enabled interrupt A condition, usually created by the operating system, during which the processor will respond to interrupt request signals of a specified class.

encryption The conversion of plain text or data into unintelligible form by means of a reversible mathematical computation.

execution context Same as *process state*.

external fragmentation Occurs when memory is divided into variable-size partitions corresponding to the blocks of data assigned to the memory (e. g., segments in main memory). As segments are moved into and out of the memory, gaps will occur between the occupied portions of memory.

field (1) Defined logical data that is part of a record. (2) The elementary unit of a record that may contain a data item, a data aggregate, a pointer, or a link.

file A set of related records treated as a unit.

file allocation table (FAT) A table that indicates the physical location on secondary storage of the space allocated to a file. There is one file allocation table for each file.

file management system A set of system software that provides services to users and applications in the use of files, including file access, directory maintenance, and access control.

file organization The physical order of records in a file, as determined by the access method used to store and retrieve them.

first come first served (FCFS) Same as *FIFO*.

first in first out (FIFO) A queuing technique in which the next item to be retrieved is the item that has been in the queue for the longest time.

frame In paged virtual storage, a fixed length block of main memory that is used to hold one page of virtual memory.

gang scheduling The scheduling of a set of related threads to run on a set of processors at the same time, on a one-to-one basis.

hash file A file in which records are accessed according to the values of a key field. Hashing is used to locate a record on the basis of its key value.

hashing The selection of a storage location for an item of data by calculating the address as a function of the contents of the data. This technique complicates the storage allocation function but results in rapid random retrieval.

hit ratio In a two-level memory, the fraction of all memory accesses that are found in the faster memory (e. g., the cache).

indexed access Pertaining to the organization and accessing of the records of a storage structure through a separate index to the locations of the stored records.

indexed file A file in which records are accessed according to the value of key fields. An index is required that indicates the location of each record on the basis of each key value.

indexed sequential access Pertaining to the organization and accessing of the records of a storage structure through an index of the keys that are stored in arbitrarily partitioned sequential files.

indexed sequential file A file in which records are ordered according to the values of a key field. The main file is

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supplemented with an index file that contains a partial list of key values; the index provides a lookup capability to reach quickly reach the vicinity of a desired record.

instruction cycle The time period during which one instruction is fetched from memory and executed when a computer is given an instruction in machine language.

internal fragmentation Occurs when memory is divided into fixed-size partitions (e.g., page frames in main memory, physical blocks on disk). If a block of data is assigned to one or more partitions, then there may be wasted space in the last partition. This will occur if the last portion of data is smaller than the last partition.

interrupt A suspension of a process, such as the execution of a computer program, caused by an event external to that process and performed in such a way that the process can be resumed.

interrupt handler A routine, generally part of the operating system. When an interrupt occurs, control is transferred to the corresponding interrupt handler, which take some action in response to the condition that caused the interrupt.

job A set of computational steps packaged to run as a unit.

job control language (JCL) A problem-oriented language that is designed to express statements in a job that are used to identify the job or to describe its requirements to an operating system.

kernel A portion of the operating system that includes the most heavily used portions of software. Generally, the kernel is maintained permanently in main memory. The kernel runs in a privileged mode and responds to calls from processes and interrupts from devices.

kernel mode A privileged mode of execution reserved for the kernel of the operating system. Typically, kernel mode allows access to regions of main memory that are unavailable to processes executing in a less-privileged mode, and also enables execution of certain machine instructions that are restricted to the kernel mode. Also referred to as *system mode* or *privileged mode*.

last in first out (LIFO) A queuing technique in which the next item to be retrieved is the item most recently placed in the queue.

lightweight process A thread.

livelock A condition in which two or more processes continuously change their state in response to changes in the other process(es) without doing any useful work. This is similar to deadlock in that no progress is made but differs in that neither process is blocked or waiting for anything.

locality of reference The tendency of a processor to access the same set of memory locations repetitively over a short period of time.

logical address A reference to a memory location independent of the current assignment of data to memory. A translation must be made to a physical address before the memory access can be achieved.

logical record A record independent of its physical environment; portions of one logical record may be located in different physical records or several logical records or parts of logical records may be located in one physical record.

macrokernel A large operating system core that provides a wide range of services.

mailbox A data structure shared among a number of processes that is used as a queue for messages. Messages are sent

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to the mailbox and retrieved from the mailbox rather than passing directly from sender to receiver.

main memory Memory that is internal to the computer system, is program addressable, and can be loaded into registers for subsequent execution or processing.

malicious software Any software designed to cause damage to or use up the resources of a target computer. Malicious software (malware) is frequently concealed within or masquerades as legitimate software. In some cases, it spreads itself to other computers via e-mail or infected floppy disks. Types of malicious software include viruses, Trojan horses, worms, and hidden software for launching denial-of-service attacks.

memory cycle time The time it takes to read one word from or write one word to memory. This is the inverse of the rate at which words can be read from or written to memory.

memory partitioning The subdividing of storage into independent sections.

message A block of information that may be exchanged between processes as a means of communication.

microkernel A small privileged operating system core that provides process scheduling, memory management, and communication services and relies on other processes to perform some of the functions traditionally associated with the operating system kernel.

mode switch A hardware operation that occurs that causes the processor to execute in a different mode (kernel or process). When the mode switches from process to kernel, the program counter, processor status word, and other registers are saved. When the mode switches from kernel to process, this information is restored.

monitor A programming language construct that encapsulates variables, access procedures and initialization

code within an abstract data type. The monitor's variable may only be accessed via its access procedures and only one process may be actively accessing the monitor at any one time. The access procedures are *critical sections*. A monitor may have a queue of processes that are waiting to access it.

monolithic kernel A large kernel containing virtually the complete operating system, including scheduling, file system, device drivers, and memory management. All the functional components of the kernel have access to all of its internal data structures and routines. Typically, a monolithic kernel is implemented as a single process, with all elements sharing the same address space.

multilevel security A capability that enforces access control across multiple levels of classification of data.

multiprocessing A mode of operation that provides for parallel processing by two or more processors of a multiprocessor.

multiprocessor A computer that has two or more processors that have common access to a main storage.

multiprogramming A mode of operation that provides for the interleaved execution of two or more computer programs by a single processor. The same as multitasking, using different terminology.

multiprogramming level The number of processes that are partially or fully resident in main memory.

multitasking A mode of operation that provides for the concurrent performance or interleaved execution of two or more computer tasks. The same as multiprogramming, using different terminology.

mutex Similar to a binary semaphore. A key difference between the two is that the process that locks the mutex (sets the value to zero) must be the one to unlock it (sets the value to 1). In contrast, it is possible for one process to lock a binary semaphore and for another to unlock it.

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- mutual exclusion** A condition in which there is a set of processes, only one of which is able to access a given resource or perform a given function at any time. See *critical section*.
- nonprivileged state** An execution context that does not allow sensitive hardware instructions to be executed, such as the halt instruction and I/O instructions.
- nonuniform memory access (NUMA) multi-processor** A shared-memory multi-processor in which the access time from a given processor to a word in memory varies with the location of the memory word.
- object request broker** An entity in an object-oriented system that acts as an intermediary for requests sent from a client to a server.
- operating system** Software that controls the execution of programs and that provides services such as resource allocation, scheduling, input/output control, and data management.
- page** In virtual storage, a fixed length block that has a virtual address and that is transferred as a unit between main memory and secondary memory.
- page fault** Occurs when the page containing a referenced word is not in main memory. This causes an interrupt and requires that the proper page be brought into main memory.
- page frame** A fixed-size contiguous block of main memory used to hold a page.
- paging** The transfer of pages between main memory and secondary memory.
- physical address** The absolute location of a unit of data in memory (e. g., word or byte in main memory, block on secondary memory).
- pipe** A circular buffer allowing two processes to communicate on the producer-consumer model. Thus, it is a first-in-first-out queue, written by one process and read by another. In some systems, the pipe is generalized to allow any item in the queue to be selected for consumption.
- preemption** Reclaiming a resource from a process before the process has finished using it.
- prepaging** The retrieval of pages other than the one demanded by a page fault. The hope is that the additional pages will be needed in the near future, conserving disk I/O. Compare *demand paging*.
- priority inversion** A circumstance in which the operating system forces a higher-priority task to wait for a lower-priority task.
- privileged instruction** An instruction that can be executed only in a specific mode, usually by a supervisory program.
- privileged mode** Same as *kernel mode*.
- process** A program in execution. A process is controlled and scheduled by the operating system. Same as *task*.
- process control block** The manifestation of a process in an operating system. It is a data structure containing information about the characteristics and state of the process.
- process descriptor** Same as process control block.
- process image** All of the ingredients of a process, including program, data, stack, and process control block.
- process migration** The transfer of a sufficient amount of the state of a process from one machine to another for the process to execute on the target machine.
- process spawning** The creation of a new process by another process.
- process state** All of the information that the operating system needs to manage a process and that the processor needs to properly execute the process. The process state includes the contents of

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the various processor registers, such as the program counter and data registers; it also includes information of use to the operating system, such as the priority of the process and whether the process is waiting for the completion of a particular I/O event. Same as *execution context*.

process switch An operation that switches the processor from one process to another, by saving all the process control block, registers, and other information for the first and replacing them with the process information for the second.

processor In a computer, a functional unit that interprets and executes instructions. A processor consists of at least an instruction control unit and an arithmetic unit.

program counter Instruction address register.

program status word (PSW) A register or set of registers that contains condition codes, execution mode, and other status information that reflects the state of a process.

programmed I/O A form of I/O in which the CPU issues an I/O command to an I/O module and must then wait for the operation to be complete before proceeding.

race condition Situation in which multiple processes access and manipulate shared data with the outcome dependent on the relative timing of the processes.

real address A physical address in main memory.

real-time System An operating system that must schedule and manage real-time tasks.

real-time Task A task that is executed in connection with some process or function or set of events external to the computer system and that must meet one or more deadlines to interact effectively and correctly with the external environment.

record A group of data elements treated as a unit.

reentrant procedure A routine that may be entered before the completion of a prior execution of the same routine and execute correctly.

registers High-speed memory internal to the CPU. Some registers are user visible; that is, available to the programmer via the machine instruction set. Other registers are used only by the CPU, for control purposes.

relative address An address calculated as a displacement from a base address.

remote procedure call (RPC) A technique by which two programs on different machines interact using procedure call/return syntax and semantics. Both the called and calling program behave as if the partner program were running on the same machine.

rendezvous In message passing, a condition in which both the sender and receiver of a message are blocked until the message is delivered.

resident Set That portion of a process that is actually in main memory at a given time. Compare *working set*.

response time In a data system, the elapsed time between the end of transmission of an enquiry message and the beginning of the receipt of a response message, measured at the enquiry terminal.

reusable resource A resource that can be safely used by only one process at a time and is not depleted by that use. Processes obtain reusable resource units that they later release for reuse by other processes. Examples of reusable resources include processors, I/O channels, main and secondary memory, devices, and data structures such as files, databases, and semaphores.

round robin A scheduling algorithm in which processes are activated in a fixed cyclic order; that is, all processes are in a circular queue. A process that cannot

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proceed because it is waiting for some event (e. g., termination of a child process or an input/output operation) returns control to the scheduler.

scheduling To select jobs or tasks that are to be dispatched. In some operating systems, other units of work, such as input/output operations, may also be scheduled.

secondary memory Memory located outside the computer system itself; that is, it cannot be processed directly by the processor. It must first be copied into main memory. Examples include disk and tape.

segment In virtual memory, a block that has a virtual address. The blocks of a program may be of unequal length and may even be of dynamically varying lengths.

segmentation The division of a program or application into segments as part of a virtual memory scheme.

semaphore An integer value used for signaling among processes. Only three operations may be performed on a semaphore, all of which are atomic: initialize, decrement, and increment. Depending on the exact definition of the semaphore, the decrement operation may result in the blocking of a process, and the increment operation may result in the unblocking of a process. Also known as a **counting semaphore** or a **general semaphore**.

sequential access The capability to enter data into a storage device or a data medium in the same sequence as the data are ordered, or to obtain data in the same order as they were entered.

sequential file A file in which records are ordered according to the values of one or more key fields and processed in the same sequence from the beginning of the file.

server (1) A process that responds to request from clients via messages. (2) In a network, a data station that provides facilities to other stations; for example, a file server, a print server, a mail server.

session A collection of one or more processes that represents a single interactive user application or operating system function. All keyboard and mouse input is directed to the foreground session, and all output from the foreground session is directed to the display screen.

shell The portion of the operating system that interprets interactive user commands and job control language commands. It functions as an interface between the user and the operating system.

spin lock Mutual exclusion mechanism in which a process executes in an infinite loop waiting for the value of a lock variable to indicate availability.

spooling The use of secondary memory as buffer storage to reduce processing delays when transferring data between peripheral equipment and the processors of a computer.

stack An ordered list in which items are appended to and deleted from the same end of the list, known as the top. That is, the next item appended to the list is put on the top, and the next item to be removed from the list is the item that has been in the list the shortest time. This method is characterized as last-in-first-out.

starvation A condition in which a process is indefinitely delayed because other processes are always given preference.

strong semaphore A semaphore in which all processes waiting on the same semaphore are queued and will eventually proceed in the same order as they executed the wait (P) operations (FIFO order).

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- swapping** A process that interchanges the contents of an area of main storage with the contents of an area in secondary memory.
- symmetric multiprocessing (SMP)** A form of multiprocessing that allows the operating system to execute on any available processor or on several available processors simultaneously.
- synchronous operation** An operation that occurs regularly or predictably with respect to the occurrence of a specified event in another process, for example, the calling of an input/output routine that receives control at a precoded location in a computer program.
- synchronization** Situation in which two or more processes coordinate their activities based on a condition.
- system bus** A bus used to interconnect major computer components (CPU, memory, I/O).
- system mode** Same as *kernel mode*.
- task** Same as *process*.
- thrashing** A phenomenon in virtual memory schemes, in which the processor spends most of its time swapping pieces rather than executing instructions.
- thread** A dispatchable unit of work. It includes a processor context (which includes the program counter and stack pointer) and its own data area for a stack (to enable subroutine branching). A thread executes sequentially and is interruptible so that the processor can turn to another thread. A process may consist of multiple threads.
- thread switch** The act of switching processor control from one thread to another within the same process.
- time sharing** The concurrent use of a device by a number of users.
- time slice** The maximum amount of time that a process can execute before being interrupted.
- time slicing** A mode of operation in which two or more processes are assigned quanta of time on the same processor.
- trace** A sequence of instructions that are executed when a process is running.
- translation lookaside buffer (TLB)** A high-speed cache used to hold recently referenced page table entries as part of a paged virtual memory scheme. The TLB reduces the frequency of access to main memory to retrieve page table entries.
- trap** An unprogrammed conditional jump to a specified address that is automatically activated by hardware; the location from which the jump was made is recorded.
- trap door** Secret undocumented entry point into a program, used to grant access without normal methods of access authentication.
- trojan horse** Secret undocumented routine embedded within a useful program. Execution of the program results in execution of the secret routine.
- trusted system** A computer and operating system that can be verified to implement a given security policy.
- user mode** The least-privileged mode of execution. Certain regions of main memory and certain machine instructions cannot be used in this mode.
- virus** Secret undocumented routine embedded within a useful program. Execution of the program results in execution of the secret routine.
- virtual address** The address of a storage location in virtual memory.
- virtual memory** The storage space that may be regarded as addressable main storage by the user of a computer system in which virtual addresses are mapped into real addresses. The size of virtual storage is limited by the addressing scheme of the computer system and by

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the amount of secondary memory available and not by the actual number of main storage locations.

weak semaphore A semaphore in which all processes waiting on the same semaphore proceed in an unspecified order (i.e., the order is unknown or indeterminate).

word An ordered set of bytes or bits that is the normal unit in which information may be stored, transmitted, or oper-

ated on within a given computer. Typically, if a processor has a fixed-length instruction set, then the instruction length equals the word length.

working set The working set with parameter Δ for a process at virtual time t , $W(t, \Delta)$, is the set of pages of that process that have been referenced in the last Δ time units. Compare *resident set*.

worm Program that can travel from computer to computer across network connections. May contain a virus or bacteria.