CS 478

Software Development for Mobile Platforms

Set 7: Files, Databases and Content Providers

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Device hardware: Internal vs. External storage

- Typical device may have two kinds of storage
- *Internal*: Flash memory in mobile device
  - Apps installed here (unless *android:installLocation* used in manifest)
  - Used for data private to applications
  - Data removed when app uninstalled
  - Usually files are not accessible to other apps
  - But hardware shared with other apps, use judiciously
  - 2 kinds of files: *Regular* (persistent) and *Cache* (temporary)
  - Typical size: 32 GB—512 GB (iPhone XS, Samsung S10)

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Device hardware: Internal vs. External storage

- *External*: Mounted storage device (e.g., SD card)
  - Typically larger than flash on device
  - But data accessible and modifiable by all apps
  - Also, may not be available if mounted storage device is removed from phone/tablet
  - Many phones do not have an SD card slot
  - Phones without card slot typically divide permanent storage into *internal* and *external partitions*
  - Size: up to 1 TB

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Options for storage of persistent data

- *SharedPreferences files*: Small, private files stored in internal memory
- *Internal storage general files*: Private general storage for an app (persistent or cached)
- *External Storage files*: Large, shared files (e.g., music, media recordings)
- *SQLite database:* Database stored on device, typically in internal storage
- *Network*: Connect to storage server
- *Content Provider*: Abstraction for all kinds of storage—Allow for sharing of large data sets between apps
- https://developer.android.com/guide/topics/data/data-storage.html

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Shared preferences

- Overview: Store **small** amounts of **primitive** data with an app
- Data persists across app executions
- Shared preferences = Set of (key, value) pairs
  - Keys are strings
  - Values can be *boolean*, *int, long, float, String*, and *Set<String>*
- Physically stored in a data file(s) owned by the application
  - Changes to preferences files are managed by an editor (i.e., instance of *SharedPreferences.Editor*) to guarantee consistency of information as file could be accessed by multiple threads
  - Getter methods defined in *SharedPreferences* class

See: https://developer.android.com/guide/topics/data/data-storage.html#pref

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Kinds of shared preferences files

1. Activity local file (activity specific)
2. App global files
3. Default app global file

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Getting local *SharedPreferences* object

- Default *SharedPreferences* file for an activity
- Call API *getPreferences()* in activity to get activity-specific preferences file
  - Defined in *Activity*
  - 1 Arg: *MODE_PRIVATE* (only one allowed now), ~~*MODE_WORLD_READABLE, MODE_WORLD_WRITEABLE*~~
  - Returns *SharedPreferences* object for calling activity
  - Suitable for general purpose use, not just storing user preferences
  - Just one file per activity
- https://developer.android.com/reference/android/app/Activity.html#getPreferences(int)

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Accessing data in *SharedPreferences* object

- Given *SharedPreferences* object, access information directly with getter methods (e.g., *getInt(), getBoolean(), getLong(), getFloat(), getString(),* etc.)
  - Args: (1) key (a *String*), and (2) default value (*int, String*, etc.)
  - Return *int, boolean, long*, etc.
  - Zero arg method *getAll()* returns *Map< String, ? >* containing all pairs (do not modify)
  - Zero arg method *edit()* returns *SharedPreferences.Editor* object
  - Method *contains(String)* returns *boolean* (obvious)
- https://developer.android.com/reference/android/content/SharedPreferences.html

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Modifying data in *SharedPreferences* object

- Send message *edit()* to *SharedPreferences* object
- Returned *SharedPreferences.Editor* instance has setter API
- Examples API methods—All return receiver (a *SharedPreferences.Editor*)
  - *putBoolean(String, boolean)*
  - *putInt(String, int)*
  - *putString(String, String)*
  - *putStringSet(String, Set<String>)*
  - *remove(String)*
- Send *commit()* message to editor to save changes to file
  - Return *true* if changes successfully applied to persistent storage
- https://developer.android.com/reference/android/content/SharedPreferences.Editor.html

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Getting app global *SharedPreferences* object

- Define files shared by all components in an application
- Use *getSharedPreferences()* in activity, service, or broadcast receiver to get application-wide preferences
  - Defined in *Context*
  - Args: (1) Name of preference file (a *String*), and (2) file mode (an *int*)
  - Return *SharedPreferences* object for app
  - Only non-deprecated mode: *MODE_PRIVATE,* ~~*MODE_WORLD_READABLE* and *MODE_WORLD_WRITEABLE*~~
- https://developer.android.com/reference/android/content/Context.html#getSharedPreferences(java.lang.String, int)

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Default preferences

- Use *getDefaultSharedPreferences(Context)* to get global application preferences used by default in application
  - Static method defined in class *PreferenceManager*
  - 1 arg: Context of application for which default preferences are returned
  - Return *SharedPreferences* object
  - Manipulate as usual (e.g., edit with *SharedPreferences.Editor* object)
- https://developer.android.com/reference/android/preference/PreferenceManager.html

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Simple *SharedPreferences* example

```
public class CalendarActivity extends Activity {
   …
   static final int DAY_VIEW_MODE = 0;
   static final int WEEK_VIEW_MODE = 1;
   private SharedPreferences mPrefs;
   private int mCurViewMode;

   protected void onCreate(Bundle savedInstanceState) {
      super.onCreate(savedInstanceState);
      SharedPreferences mPrefs = getSharedPreferences(“elMiFile”, MODE_PRIVATE);
      mCurViewMode = mPrefs.getInt("view_mode", DAY_VIEW_MODE);
   }

   protected void onPause() {
      super.onPause();
      SharedPreferences.Editor ed = mPrefs.edit();
      ed.putInt("view_mode", mCurViewMode);
      ed.commit();
   }
}
```

Imaginary activity in a *Calendar* app.

Declaration of *SharedPreferences* field.

Read existing preferences from file.

Getter methods use default values.

Get a preferences editor to modify preferences file.

Update “view_mode” entry and commit.

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Using general-purpose files

- Files can be stored in internal memory or external memory (e.g., SD card)
- Internal storage: Use for smaller private data
  - Advantage: Privacy
  - Disadvantage: Data erased when app uninstalled
- External storage: Use for larger, public data (e.g., media files); however, private areas available on external memory as well
  - Keep data that should not be lost when an app is uninstalled (e.g., pictures, music, etc.)

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Java's *File* class

- "Abstract representation of a file or directory pathname" (https://developer.android.com/reference/java/io/File.html)
- Abstract representation independent of OS notations (e.g., \ vs. /)
- Actual file or directory may or may not exist
- Useful for navigating file systems, while possibly adding and deleting files
- Complex rules for forming path names
- Examples of constructors
  - *File(String)* – Constructs new instance using input path
  - *File(URI)* – Input path specified as a URI

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Java's *File* class

- Main methods
  - *createNewFile()* : boolean – Creates actual empty file in file system
  - *canRead()* : boolean – Indicates whether context can read actual file
  - *canWrite()* : boolean – Indicates whether context can write actual file
  - *delete()* : boolean – Deletes actual file
  - *exists()* : boolean – Indicates whether actual file exists in file system
  - *isDirectory()* : boolean – Indicates whether actual file is a directory
  - *list()* : String[] – List directory (receiver must represent a directory)
  - *mkdir(), mkdirs()* : boolean – Makes directory (with parents if needed)
  - *toURI()* : URI – Returns URI for this file (receiver)

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Reading and writing bytes in file

- Java classes *FileInputStream* and *FileOutputStream* support reading and writing of bytes in a given file
- Get *FileInputStream* by calling *Context* method *openFileInput(String)*
  - Gets *String* with name of private file
  - Returns *FileInputStream* instance
  - Can throw *FileNotFoundException*
- https://developer.android.com/reference/android/content/Context.html
  https://developer.android.com/reference/java/io/FileInputStream.html
  https://developer.android.com/reference/java/io/FileOutputStream.html

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Writing bytes to a file

- Get *FileOutputStream* with *Context* method *openFileOutput(String, int)*
  - Opens private file
  - Params: (1) *String* with name of private file, (2) *int* specifying file mode (can be MODE_PRIVATE or MODE_APPEND)
  - Will create file if it does not exist
  - MODE_APPEND will append content to file rather than erasing it
  - Returns *FileOutputStream* instance
- http://developer.android.com/reference/android/content/Context.html
  http://developer.android.com/reference/java/io/FileOutputStream.html

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Reading characters from file

- Class *InputStreamReader* converts byte stream (e.g., obtained from *FileInputStream* instance) into character stream
- Get an *InputStreamReader* by *FileInputStream* by calling constructor with *FileInputStream* arg, e.g,

  new *InputStreamReader(aFileInputStream)*

  - Part of Java
  - Main method: *read()* (reads one character, return it as *int*)
- Still, a bit inconvenient to use; would rather get whole lines or words at once from input file
- Doc: http://developer.android.com/reference/java/io/InputStreamReader.html

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Reading whole lines from file

- Class *BufferedReader* buffers character stream until end-of-line
- Get *BufferedReader* from *InputStreamReader* by calling constructor with *InputStreamReader* arg

  new *BufferedReader(InputStreamReader)*

  - Again, part of Java
  - Main method: *readLine()* (reads one line of text, return it as a *String*)
- Now we are talking…
- Doc: http://developer.android.com/reference/java/io/BufferedReader.html

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Writing (multi-line) text to file

- Class *OutputStreamWriter* turns character stream into byte stream
- The inverse of *InputStreamReader*
- Get *OutputStreamWriter* from *FileOutputStream* by calling constructor with *FileOutputStream* arg

  new *OutputStreamWriter(aFileOutputStream)*

  - Again, part of Java
  - Main methods: *write(int), flush(), close()* (closes also associated *FileOutputStream*)
  - Method *write(String, int_offset, int_length)* writes a portion of a string
- Doc: http://developer.android.com/reference/java/io/OutputStreamWriter.html

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Writing (multi-line) text to file (cont'd)

- Class *BufferedWriter* writes multiple lines of text to output stream
- Get *BufferedWriter* from *OutputStreamWriter* by calling constructor with *OutputStreamWriter* arg

  new *BufferedWriter(OutputStreamWriter)*

  - Again, part of Java
  - Main methods: *write(String)* (inherited from *Writer*), *close(), flush(), newLine()…*
- Like *BufferedReader,* a useful class
- Doc: http://developer.android.com/reference/java/io/BufferedWriter.html

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Working with external storage

- Similar to case of internal storage
- Big caveat: External storage could be added or removed without warning (e.g., an SD card)
- Good idea: Before working with external memory, check state
- Class *Environment* defines **static** method *getExternalStorageState()* (overloaded, no-arg or file path arg)
- Return string indicate state of external storage, e.g.,
  - MEDIA_REMOVED, MEDIA_MOUNTED, MEDIA_UNMOUNTED, MEDIA_EJECTING, MEDIA_MOUNTED_READ_ONLY, etc.
- Doc: https://developer.android.com/reference/android/os/Environment.html

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Working with external memory (cont'd)

- Another caveat: Needs permissions to read and write to external memory since API 16 (changed for private files since KK, though)
  - android.permission.READ_EXTERNAL_STORAGE
    android.permission.WRITE_EXTERNAL_STORAGE
  - Dangerous level: Must ask user at R-T in post-MM model
  - Not needed for app-specific files obtained with *getExternalFilesDir()* since KK (API 19)
- E.g.,

```
<manifest ...>
  <uses-permission
     android:name="android.permission.WRITE_EXTERNAL_STORAGE" />
  …
```

- Doc: https://developer.android.com/guide/topics/data/data-storage.html

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Getting shared file in external memory

- Paradigm:
  1. Get path to external directory (an instance of *File*)
  2. Create directory at that path
  3. Create a new *File* instance specifying path (a *File*) and file name (a *String*)
- Step 1 can be accomplished in different ways (see next)
- Class *Environment* manages general device information
- Doc: https://developer.android.com/reference/java/io/File.html
- Doc: https://developer.android.com/reference/android/os/Environment.html

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1. Getting directory path

- Static *Environment* method *GetExternalStoragePublicDirectory()*
  - Arg string specifies the type of content to be stored in directory, e.g., DIRECTORY_MUSIC, DIRECTORY_PICTURES, DIRECTORY_MOVIES, DIRECTORY_DOWNLOADS, etc.
  - Returns *File* object
- Alternatively use *Context* method *GetExternalFilesDir()*
- Again, arg specifies the type of content to be stored (see above)
  - Directory is considered private, no permissions required of owner app (KitKat and subsequent versions)
  - Other apps require usual permissions to read/write files there
- Doc: https://developer.android.com/reference/android/content/Context.html
  Doc: https://developer.android.com/reference/android/os/Environment.html

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2. Creating directory + 3. Creating file in directory

- Use path returned by one of two earlier methods, to create directory, e.g., *path.mkdirs()* (defined in *File*)
  - Return *true* if creation was successful, *false* if directory already existed or failed to create directory
- If directory exists, now create the file by passing directory (a *File*) and file name (a *String*) to *File* constructor

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SQLite databases

- Support for DBs accessible within an app, not shared with other apps
- SQLite is a full-fledged relational DBMS, not just for Android
  - SQL (Sequential Query Language) is the universal language for programming relational databases
  - Relational databases organize data in tables
- Compliant with SQL-92 standard except for few missing features:
  - Few ALTER TABLE options (support RENAME TABLE and ADD COLUMN; no support for DROP COLUMN, etc.)
  - VIEWS are read-only, etc.
- SQLite footprint is very small wrt to regular databases, with support for query optimization, fast access to data, ACID transactions

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More on SQLite

- ACID transactions, just like any database
  - Atomic (all or nothing transaction effects)
  - Consistent (transactions preserve database constraints)
  - Isolated (Concurrent transactions are serializable)
  - Durable (Transaction effects are permanent even in the event of software crashes)
- No client/server model with multiple server threads
  - Library implementing SQLite is linked with app using it
  - Dynamic linking available
  - Faster access than regular DB because no IPC involved

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Working with databases in Android

- New classes needed for working with *SQLite* databases
  - *SQLiteOpenHelper* – Abstract class to manage database creation and version management
  - *ContentValues* – Set of <*key, value*> pairs specifying database row
  - *Cursor* – Interface defining iterator over values returned by DB queries
  - *SimpleCursorAdapter* – Class mapping cursors (e.g, returned from database queries) to list items suitable for display according to some XML layout specification
  - *SQLiteDatabase* – DB object
- https://developer.android.com/training/data-storage/sqlite.html

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Creating SQLite database

- Define class that extends *SQLiteOpenHelper*
  - Helps create/open/update DB
  - Define SQL statements as strings, pass strings to SQLite DB
  - Methods *getReadableDatabase()* and *getWritableDatabase()* will return *SQLiteDatabase* object (no args)
    - DB created if it does not exist, opened if it exists
    - Do not call from UI thread, as these methods can be slow
  - Method *close()* closes DB

https://developer.android.com/reference/android/database/sqlite/SQLiteOpenHelper.html

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Subclassing *SQLiteOpenHelper:* Methods needed

1. Constructor
2. *onCreate(SQLiteDatabase): void –*
3. *onUpgrade(SQLiteDatabase, int, int): void –*
4. (optional) *onOpen(SQLiteDatabaset): void –*

Caveat: Following methods inherited from superclass *SQLiteOpenHelper* need not be redefined

- *GetReadableDatabase(): SQLiteDatabase*
- *GetWritableDatabase(): SQLiteDatabase*

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Subclassing *SQLiteOpenHelper:* Constructor (cont'd)

- Constructor must invoke superclass's constructor
- Superclass *SQLiteOpenHelper* has multiple constructors, basic constructor takes four parameters
  1. *Context* context – the usual
  2. *String* name – name of database file, **null** if database held in RAM
  3. *SQLiteDatabase.CursorFactory* factory – Java interface used to create cursor objects, **null** for default factory
  4. *int* version – Version number, starting at 1

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Subclassing *SQLiteOpenHelper:* Constructor

- Constructor returns helper object for creating/opening/managing a database
- Database not created or opened until methods *getWritableDatabase()* or *getReadableDatabase()* are called
- https://developer.android.com/reference/android/database/sqlite/SQLiteDatabase.CursorFactory.html

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Class *SQLiteOpenHelper:* Methods

- *getReadableDatabase()*: *SQLiteDatabase*
  - Create and/or open a database, could be read-only
  - *SQLiteDatabase* instance returned manages actual database, is valid until *close()* or *getWriteableDatabase()* called
  - Do not call from UI thread!
- *getWritableDatabase()*: *SQLiteDatabase*
  - Create and/or open a database used **for reading and writing data**
  - First time calling this method will trigger calls to *onCreate(), onUpgrade(),* and *onOpen()*
  - Do not call from UI thread!
- Either way: Do not forget to call *close()* when done

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Subclassing *SQLiteOpenHelper:* Callback methods

Define three key abstract methods from *SQLiteOpenHelper*, all return **void**

- *onCreate(SQLiteDatabase)* – Called when database created the first time
  - Create and populate database tables, e.g., using "CREATE TABLE" and "INSERT INTO" commands
- *onUpgrade(SQLiteDatabase, int, int)* – Called when database opened with a different version number than the previous version number
  - Typical actions: add and/or drop tables, add columns to table, etc.
  - **int** args specify old and new version numbers
  - Execute DROP TABLE, ALTER TABLE commands, etc.
- (optional) *onOpen(SQLiteDatabase)* – Called after database is opened (e.g., with *getReadableDatabase()* or *getWritableDatabase()*)

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Class *ContentValues*

- Class for representing database tuples (rows)
- Set of (*key*, *value*) pairs, where *keys* are column names and *values* are column values in the tuple
- Values are types that can be stored in a database (e.g., primitive types and *Strings*)
- https://developer.android.com/reference/android/content/ContentValues.html

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Class *ContentValues* (cont'd)

- Main methods:
  - Most getters take key as *String*, return value of appropriate type:
    - *get(String): Object*
    - *getAsBoolean(String): Boolean*
    - *getAsInteger(String): Integer*
    - *getAsString(String): String*
  - Other getters:
    - *keySet(): Set<String>*
    - *valueSet(): Set<Entry<String,Object>>*
    - *size(): int* (obvious)
    - *toString(): String*

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Class *ContentValues* (cont'd)

- Main methods:
  - Setters (all **void**):
    - *put(String, Boolean)*
    - *put(String, Integer)*
    - *put(String,String)*
    - *putAll(ContentValues)*, etc.
- Other setters: *void remove(String); void clear()*

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Interface *Cursor*

- Java Interface that "… provides random read-write access to the result set returned by a database query."
- Implement by extending abstract class *AbstractCursor*
- Predefined concrete subclass *SQLiteCursor* often gets job done
- An extension of the *Iterator* design pattern
- Also, allows observers on the dataset or the source backing data set (see, e.g., *Observer* pattern)
- Thread unsafe by default, if multiple threads can access same *Cursor* object, you must write thread-safe code
- Rich APIs allow to retrieve content from database query (see next)
- https://developer.android.com/reference/android/database/Cursor.html

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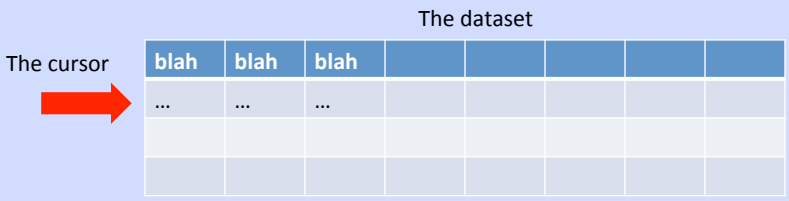
Interface *Cursor*

- Logical view of a cursor



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Java interface *Cursor*

- Main APIs:
  - *getCount()*: *int* – Return the number of rows in the data set
  - Cursor movement (all *boolean*, return *false* if empty cursor, or if element does not exist):

    moveToNext(), moveToFirst(), moveToLast(), moveToPrevious(), moveToPosition(int position), *move(int* offset), etc.
  - Testing (all boolean): *isFirst(), isLast(), isBeforeFirst(), isAfterLast()*
  - DB value getters (all take column index):

    int getInt(int), String getString(int), double getDouble(int), etc.
  - Other getters:

    String[] getColumnNames(), String getColumnName(int), int getColumnIndex(String), etc.

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Java interface *Cursor*

- Main APIs (continued):
  - Termination API: *close()* : *void*
  - Observer API (all *void)*:

    registerDataSetObserver(DataSetObserver), registerContentObserver(ContentObserver), unregisterDataSetObserver(DataSetObserver), unregisterContentObserver(ContentObserver)
  - Automatically notify registered observers of changes in data set associated with this cursor or data repository backing a data set
- *DataSetObserver* and *ContentObserver* are abstract classes declaring observer behavior (e.g., with method *onChange()* and *onChanged()*)

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Class *SQLiteCursor*

- Concrete subclass of *AbstractCursor* by way of *AbstractWindowedCursor*

  "A Cursor implementation that exposes results from a query on a SQLiteDatabase. SQLiteCursor is not internally synchronized so code using a SQLiteCursor from multiple threads should perform its own synchronization when using the SQLiteCursor."

  https://developer.android.com/reference/android/database/sqlite/SQLiteCursor.html
- Customer beware: Class not designed to be thread-safe
  - If cursor accessed by multiple threads, implement appropriate synchronization yourself

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Class *SimpleCursorAdapter*

- Concrete *Cursor* implementation that maps database columns to text views and image views defined in *res/layout* XML files http://developer.android.com/reference/android/widget/SimpleCursorAdapter.html
- Yet another use of *Adapter* pattern from Go4 system
- Must bind columns from cursor to text views or image views in XML file
- *SimpleCursorAdapter(Context context, int layout, Cursor c, String[] from, int[] to, int flags)*
  - Constructor takes (1) context of list view, (2) layout (XML) file id, (3) cursor, (4) column names to bind, (5) text views that will display columns, (6) flags
- Method *bindView(View, Context, Cursor)* : *void* – Perform binding

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Class *SQLiteDatabase*

- Encapsulate SQLite database
  https://developer.android.com/reference/android/database/sqlite/SQLiteDatabase.html
- A largish class supporting database creation, deletion and operations, such as queries and transactions
- DB Transaction = Sequence of queries
- Transactions are ACID (Atomic, Consistent, Isolated and Durable)
- Template of a typical transaction:
  - *beginTransaction()* : *void*
  - Sequence of queries
  - *endTransaction()* : *void*

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Class *SQLiteDatabase* : Query methods

- Methods mirror queries in relation DB systems, e.g.,
  - SELECT, UPDATE, DELETE, etc.
- A largish class supporting database creation, deletion and operations, such as queries and transactions
- Key methods
  - *execSQL(String)* : *void*
  - *beginTransaction(), endTransaction()* : *void*
  - *insert(String table, String nullHack, ContentValues values)* : *long*
  - *delete(String table, String whereClause, String[] whereArgs)* : *int*
  - *query(String table, …)* : *Cursor*

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The *query()* method

- API for querying a database table
- *query()* message is mapped to corresponding database SELECT cmd
- Arguments:
  - *String* table = name of table to be queried
  - *String[]* columns = columns to be returned
  - *String* selection = condition on rows to be returned (WHERE clause)
  - *String[]* selectionArgs = Arguments to be inserted for ?s in selection
  - *String* groupBy = GROUP BY clause
  - *String* having= HAVING clause
  - *String* orderBy = ORDER BY clause

https://developer.android.com/reference/android/database/sqlite/SQLiteDatabase.html

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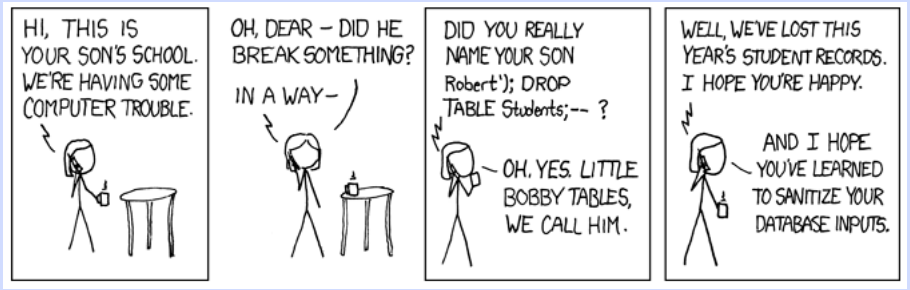
Why separate selection and selection arguments?

- Prevent database injection attacks
  - User input can become part of SQL statement
  - Check statements entered by user **before** passing along to database
  - From WebComic https://xkcd.com/327/



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not covered

Content providers

- One of four basic elements of Android apps (along with activities, receivers, and services)
- Used for sharing information among apps
  - No need for provider unless data shared among apps!
- Goal: Provide uniform interface to different kinds of data stores
  - Abstract away how data stored
  - Interface similar to relational database, but actual data could be stored anywhere (RAM, internal + external storage, network, etc.)
  - So, think tables, rows (records), columns (attributes), etc.

https://developer.android.com/guide/topics/providers/content-providers.html
https://developer.android.com/reference/android/content/ContentProvider.html

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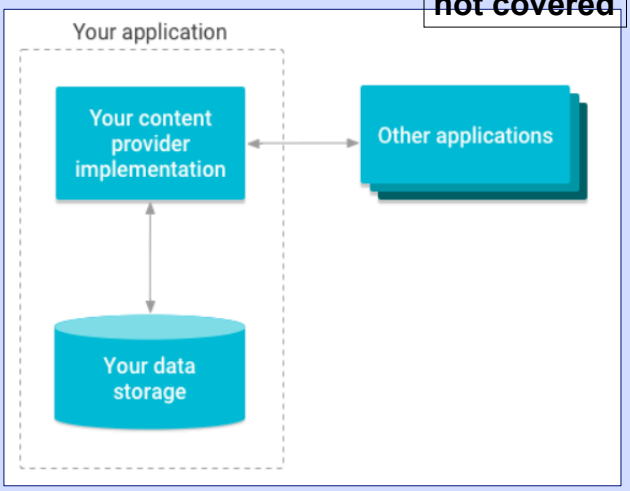
not covered

Abstract view of content provider



- Source: https://developer.android.com/guide/topics/providers/content-providers.html

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not covered

Content providers (cont'd)

- Most popular predefined providers:
  - Contacts provider
  - Calendar provider
  - Email provider
  - Browser provider
  - and many more
- You may define new providers as well
- Must define content provider if you want to:
  1. Implement custom suggestions in app
  2. Cut/copy/paste data from your app to other apps

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not covered

Content providers (cont'd)

- Outline of this section:
  1. SQLite databases
  2. Using providers: Authorities, contracts, content resolvers and content providers
  3. Creating new providers

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SQLite databases and content providers

not covered

- Data accessible through content provider is often stored in an SQLite database
  - No particular requirements on the database in this case
- However, if data in content provider must be displayed in an *AdapterView* (e.g., *ListView* or *GridView*), underlying table(s) must contain an integer primary key column named *_ID*
  - This was the case for *DataManagementSQL* app
  - This key will be used by adapter to enumerate elements to be displayed

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Working with content providers

not covered

- First, make sure content provider is needed
  - Provider may not be needed if application does not share data with other apps
- However, content provider will be needed, e.g., if your app…
  - Sends data to widget
  - Returns custom suggestions use *SearchRecentSuggestionsProvider*
  - Synchronizes data with remote server using concrete subclass of class *AbstractThreadedSyncAdapter*
  - Loads data to UI using *CursorLoader*

https://developer.android.com/guide/topics/providers/content-provider-basics.html

https://developer.android.com/reference/android/content/SearchRecentSuggestionsProvider.html

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not covered

Working with content providers

- Clients of content providers must use a *ContentResolver* instance to access content provider defined by another app
  - Get content resolver by calling no-arg method *getContentResolver()* (defined by *Context*)
- Content resolver's responsibilities:
  1. Find appropriate provider, given a *Content URI*
  2. Manage all IPC between client app and other app's *ContentProvider*
- Content resolver uses *content URI* to identify provider and its data
- Client often uses *CursorLoader* instance to access data in content resolver

https://developer.android.com/reference/android/content/ContentResolver.html

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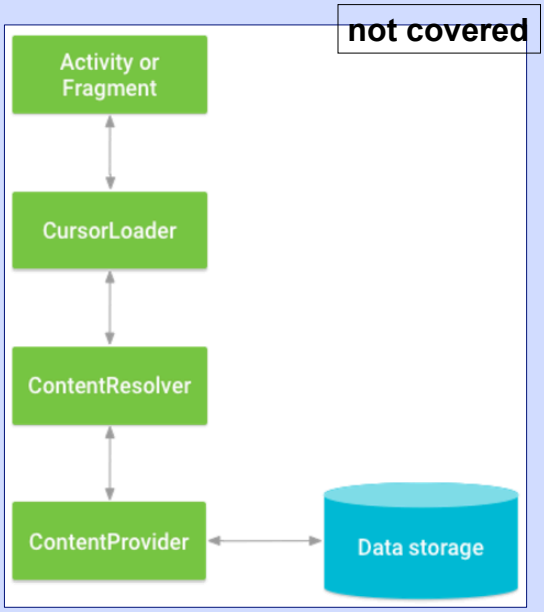
Diagram of typical provider use



Source:
https://developer.android.com/guide/topics/providers/content-provider-basics.html

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Content URIs

- Goal: Identify content provider and specific data in the provider
- Format: Special URI with *content* scheme

  content://*authority/path/id*

  - *content:* scheme identifier (vs. *tel*, *http*, etc.)
  - *authority:* id of the content provider, often its package name
  - *path:* (optional) path within provider (e.g., a table name or a directory structure) — zero or many segments separated by "/" chars
  - *id:* (optional) specific location (e.g., a row) within the *path*
- E.g., **content://com.android.chrome/bookmarks/search_suggest_query**
- https://developer.android.com/reference/android/content/ContentUris.html

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Finding a provider

- Content resolver takes a content URI object and looks up URI's authority in system-wide table of registered providers
- https://developer.android.com/guide/topics/providers/content-provider-basics.html

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Building content URIs

- Helper classes *ContentUris* and *Uri.Builder*
- *Uri.Builder* allows you to build *ContentUri* instance incrementally
  - *appendPath(String* newSegment*)*
  - *authority(String* authority*)*
  - *query(String* query*)*
  - *build()* → *Uri* instance
- https://developer.android.com/reference/android/content/ContentUris.html
  https://developer.android.com/reference/android/net/Uri.Builder.html

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Class *ContentResolver*

- Main: Support Inter-Process Communication (IPC) between process running client app and process owning content provider
- Also, support CRUD functionality for data store hosted by provider
  - Create
  - Retrieve
  - Update
  - Delete
- Always use *content URI* to identify data to be accessed and/or modified

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Main *ContentResolver* methods

- Methods to support CRUD functionality (without signatures)
  - *query()* – select operation on content URI
  - *insert()* – insert row in content URI
  - *delete()* – delete rows in content URI
  - *update()* – update rows in content URI

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Key *ContentResolver* methods: *query()*

- Perform SELECT query on provider – Return *Cursor* instance
- Parameters:
  - *Uri uri* – authority of content to retrieve (either table or row)
  - *String[] projection* – list of column names to return
  - *String selection* – a WHERE clause (except for word "WHERE") restricting range of rows to be returned
  - *String[] selectionArgs* – values matching "?" marks from *selection* (by position)
  - *String sortOrder* – a ORDER BY clause (except for words "ORDER BY") defining order of rows returned by query
- https://developer.android.com/guide/topics/providers/content-provider-basics.html

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Key *ContentResolver* methods: *insert()*

- Inserts new row in table
- If content provider supports transactions, insertion is atomic
- Parameters:
  - *Uri uri* – content URI of table
  - *ContentValues values* – Initial values of columns in row
- Passing empty *ContentValues* object inserts empty row
- Return value: *Uri* of inserted row

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Key *ContentResolver* methods: *delete()*

- Delete rows in table
- If content provider supports transactions, deletion is atomic
- Parameters:
  - *URI uri* – authority of table or row
  - *String where* – WHERE clause (excluding keyword "WHERE")
  - *String[] selectionArgs* – Args matching "?" marks in *where* clause
- Return value: number of rows deleted (an *int*)

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Key *ContentResolver* methods: *update()*

- Updates rows in table
- If content provider supports transactions, updates are atomic
- Parameters:
  - *Uri uri* – authority of table or row to be modified
  - *ContentValues values* – The new field values
  - *String where* – WHERE clause (excluding "WHERE")
  - *String[] selectionArgs* – Args matching "?" marks in *where* clause
- **null** field value in *values* removes existing field value (now empty)
- Throws *NullPointerException* (unchecked) if *uri* or *values* is **null**
- Return value: number of rows updated (an *int*)

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Additional *ContentResolver* APIs

- Observer API: register and unregister observers
  - *registerContentObserver(Uri, ContentObserver)*
  - *unregisterContentObserver(ContentObserver)*
  - Observers notified when provider at specified*Uri* changes
- To use, extend abstract class *ContentObserver*, possibly overriding method *onChange()*
- Synchronization API with underlying content provider
- Streaming APIs (e.g., when content provider encapsulates media data)

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Displaying query's results

Similar to case of *SQLiteDatabase* query

- Typically results displayed in *ListView* object
- Method *getCount()* of class *Cursor* returns number of items in receiver
- Link cursor to *ListView* by supplying adapter
  - Again, class *SimpleCursorAdapter* often does it
  - *SimpleCursorAdapter(Context c, int layout, Cursor cursor, String[] from, int[] to)*
  - *from* argument specifies column names
  - *to* argument specifies views (by their *id*) that will display matching column (by position)
  - *cursor* could be **null** (not queried yet)

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More on class *SimpleCursorAdapter*

Additional key methods

- *bindView(View v, Context c, Cursor cursor)* : *void*
  - Receiver is *SimpleCursorAdapter* instance
  - Receiver binds all fields names in *to* arg with cursor columns specified in *from* arg
- *swapCursor(Cursor c)* : *Cursor*
  - Swaps new cursor, returning old cursor
- https://developer.android.com/reference/android/widget/SimpleCursorAdapter.html

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Batch access to content provider

- Useful when multiple insertions (i.e., rows) needed
  - Goal: Coalesce multiple provider access operations into a single one
- Method:
  1. Create *ArrayList* of class *ContentProviderOperation*
  2. Pass *ArrayList* instance to *applyBatch()*
- *applyBatch(String authority, ArrayList<CPO> operations)*
  - Applies all *operations* to provider, returns array of *ContentProviderResult* objects
- https://developer.android.com/reference/android/content/ContentProviderOperation.html

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Provider permissions

- Provider app must specify permissions that other apps must have in order to use the content provider
  - Provider is not exported unless it requires a permission of its clients
- Permissions
  - Define bespoke permission with <permission …/> clause in AndroidManifest.xml file of provider app
  - Require permission using android:permission attribute in provider tag
  - Client apps: Declare <uses-permission /> tag in AndroidManifest.xml to be able to use provider

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Defining content providers

Recipe for defining new content provider

1. Define storage base, e.g., SQLite database or file
2. Extend framework class *ContentProvider*
3. Define authority string, content URIs, column names, permissions that clients must have to use provider.
4. (Optional) Create final *Contract* class specifying names for things in Item 3
   - Supply *Contract* class to clients as a .jar file that they'll compile in their apps
5. Declare provider component in *AndroidManifest.xml* file

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Defining *ContentProvider* subclass

- Required methods – Same signature as identically-named *ContentResolver* methods
  - *query()* -- Could be called from multiple threads
  - *insert()*
  - *update()*
  - *delete()*
  - *getType(Uri)* : *String* – Returns MIME type of arg URI
  - *onCreate()* : *boolean* – Called when app containing provider is started (Beware: do not block UI)
- **All except *onCreate()* must be thread-safe**
- https://developer.android.com/guide/topics/providers/content-provider-creating.html

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Defining provider permissions

- Define permissions that other apps must have to read/write data to content exposed by provider
- Content must be stored in private files, consider internal memory
  - If using public files, permission is meaningless as other apps can access content directly
- Caveat: Without permissions, private data backing your provider will be exposed
  - See lectures on permissions on how to define new permissions
  - **Specified permissions must be granted at install time even in the post-MM model**
- https://developer.android.com/guide/topics/providers/content-provider-creating.html

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Declaring *ContentProvider* element

- Declare provider in *AndroidManifest.xml* file using <provider> tag

```
<provider android:authorities="semicolon-separated-list”
        android:name="name-of-class”
        android:process=":local-process"
        android:permission="string”
        android:readPermission="string”
        android:writePermission="string”
        android:grantUriPermission=["true" | "false”]
        android:syncable=["true" | "false”] >
</provider>
```

- https://developer.android.com/guide/topics/manifest/provider-element.html

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