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CS 4604: Introduction to Database Management Systems

B. Aditya Prakash

Lecture #1: Introduction

Based on material by Profs. T. M. Murali and Christos Faloutsos

Course Information

- **Instructor**

  B. Aditya Prakash, Torg 3160 F, badityap@cs.vt.edu
  - Office Hours: 2-3:15pm Tuesdays and Thursdays
  - Include string **CS 4604** in subject

- **Teaching Assistant**

  Qianzhou Du, McBryde 106, qiand12@vt.edu
  - Office Hours: 1:30-3:30pm Mondays and Wednesdays

- **Class Meeting Time**

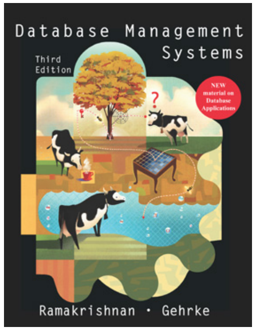
  Tuesdays and Thursdays 3:30-4:45pm Randolph Hall 331

- **Keeping in Touch**

  Course web site http://courses.cs.vt.edu/~cs4604

  updated regularly through the semester
  - *Piazza link on the website*

Textbook



- **Required**

  Database Management Systems, by Raghu Ramakrishnan and Johannes Gehrke. 3rd Ed. McGraw Hill.

  Web page for the book (with errata)

  http://pages.cs.wisc.edu/~dbbook/

- *Optional*:
  - Garcia-Molina, Ullman and Widom, 3rd Ed.
  - Silberschatz, Korth and Sudarshan, 6th Ed.

Pre-reqs and Force-adds

- Prerequisites: a grade of C or better in CS 3114, senior standing
  - every student must fill out **a pre-requisite form**, and must return it **to me at the end of the class** in order to remain enrolled
- Force-add requests:
  - Please fill out the **add form as well**, and return **to me at the end of the class**
  - We (=me or the dept) will let you know by this week

Course Grading

Homework	30%	6-7
Midterm exam	20%	(Tentative) March 6, Thur., in class
Final exam	30%	May 10, Saturday, 7:45am-9:45am
Course project	20%	3 assignments

- Project is spread over 3 deliverables
- Submit hard copies of homeworks and project assignments at the start of class on the due date
- Each class has required reading (on course web page)
- No Pop-Quizzes ☺

Course Project

- Project overview
  http://courses.cs.vt.edu/~cs4604/Spring14/project/project.html
- 2, or 3 persons per project.
- Project runs the entire semester with regular assignments and a final implementation assignment.

Class Policies

- Make sure you go through the detailed policies on website:

http://courses.cs.vt.edu/~cs4604/Spring14/policies.html

- Late policy: 4 'slip' days
- Exams: no aids allowed, except:
  - 1 page with your notes (both sides), for the midterm
  - 2 such pages, for the final

Why Study Databases?

- ***Academic***
  - Databases involve many aspects of computer science
  - Fertile area of research
  - Three Turing awards in databases
- ***Programmer***
  - a plethora of applications involve using and accessing databases
- ***Businessman***
  - Everybody needs databases => lots of money to be made
- ***Student***
  - Get those last three credits and I don't have to come back to Blacksburg ever again!
  - Google, Oracle, Microsoft, Facebook etc. will hire me!
  - Databases sound cool!
  - ???

What Will You Learn in CS 4604?

- Implementation
  - What is under-the-hood of a DB like Oracal/MySQL?
- Design
  - How do you model your data and structure your information in a database?
- Programming
  - How do you use the capabilities of a DBMS?

- CS 4604 achieves a balance between
  - a firm theoretical foundation to designing moderate-sized databases
  - creating, querying, and implementing realistic databases and connecting them to applications

Course Outline

- Weeks 1–4: Query/Manipulation Languages and Data Modeling
  - Relational Algebra
  - Data definition
  - Programming with SQL
  - Entity-Relationship (E/R) approach
  - Specifying Constraints
  - Good E/R design
- Weeks 5–8: Indexes, Processing and Optimization
  - Storing
  - Hashing/Sorting
  - Query Optimization
  - NoSQL and Hadoop
- Week 9-10: Relational Design
  - Functional Dependencies
  - Normalization to avoid redundancy
- Week 11-12: Concurrency Control
  - Transactions
  - Logging and Recovery
- Week 13–14: Students' choice
  - Practice Problems
  - XML
  - Data mining and warehousing

What is the goal of a DBMS?

- Electronic record-keeping

  Fast and ***convenient*** access to information

- DBMS == database management system
  - `Relational' in this class
  - data + set of instructions to access/manipulate data

What is a DBMS?

- Features of a DBMS
  - Support massive amounts of data
  - Persistent storage
  - Efficient and convenient access
  - Secure, concurrent, and atomic access

- Examples?
  - Search engines, banking systems, airline reservations, corporate records, payrolls, sales inventories.
  - New applications: Wikis, social/biological/multimedia/scientific/geographic data, heterogeneous data.

Features of a DBMS

- Support **massive** amounts of data
  - Giga/tera/petabytes
  - Far too big for main memory
- **Persistent** storage
  - Programs update, query, manipulate data.
  - Data continues to live long after program finishes.
- **Efficient** and **convenient** access
  - Efficient: do not search entire database to answer a query.
  - Convenient: allow users to query the data as easily as possible.
- **Secure**, **concurrent**, and **atomic** access
  - Allow multiple users to access database simultaneously.
  - Allow a user access to only to authorized data.
  - Provide some guarantee of reliability against system failures.

Example Scenario

- Students, taking classes, obtaining grades
  – Find my GPA
  – <and other ad-hoc queries>

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Obvious solution 1: Folders

- Advantages?
  - Cheap; Easy-to-use
- Disadvantages?
  - No ad-hoc queries
  - No sharing
  - Large Physical foot-print

Obvious Solution++

- Flat files and C (C++, Java…) programs
  - E.g. one (or more) UNIX/DOS files, with student records and their courses

Obvious Solution++

- Layout for student records?
  - CSV ('comma-separated-values')

```
Hermione Grainger,123,Potions,A
Draco Malfoy,111,Potions,B
Harry Potter,234,Potions,A
Ron Weasley,345,Potions,C
```

Obvious Solution++

- Layout for student records?
  - Other possibilities like

`Hermione Grainger,123`	`123,Potions,A`
`Draco Malfoy,111`	`111,Potions,B`
`Harry Potter,234`	`234,Potions,A`
`Ron Weasley,345`	`345,Potions,C`

Problems?

- inconvenient access to data (need ‘C++’ expertize, plus knowledge of file-layout)
  – data isolation
- data redundancy (and inconsistencies)
- integrity problems
- atomicity problems
- concurrent-access problems
- security problems
- …….

Problems-Why?

- Two main reasons:
  - file-layout description is buried within the C programs and
  - there is no support for transactions (concurrency and recovery)

DBMSs handle exactly these two problems

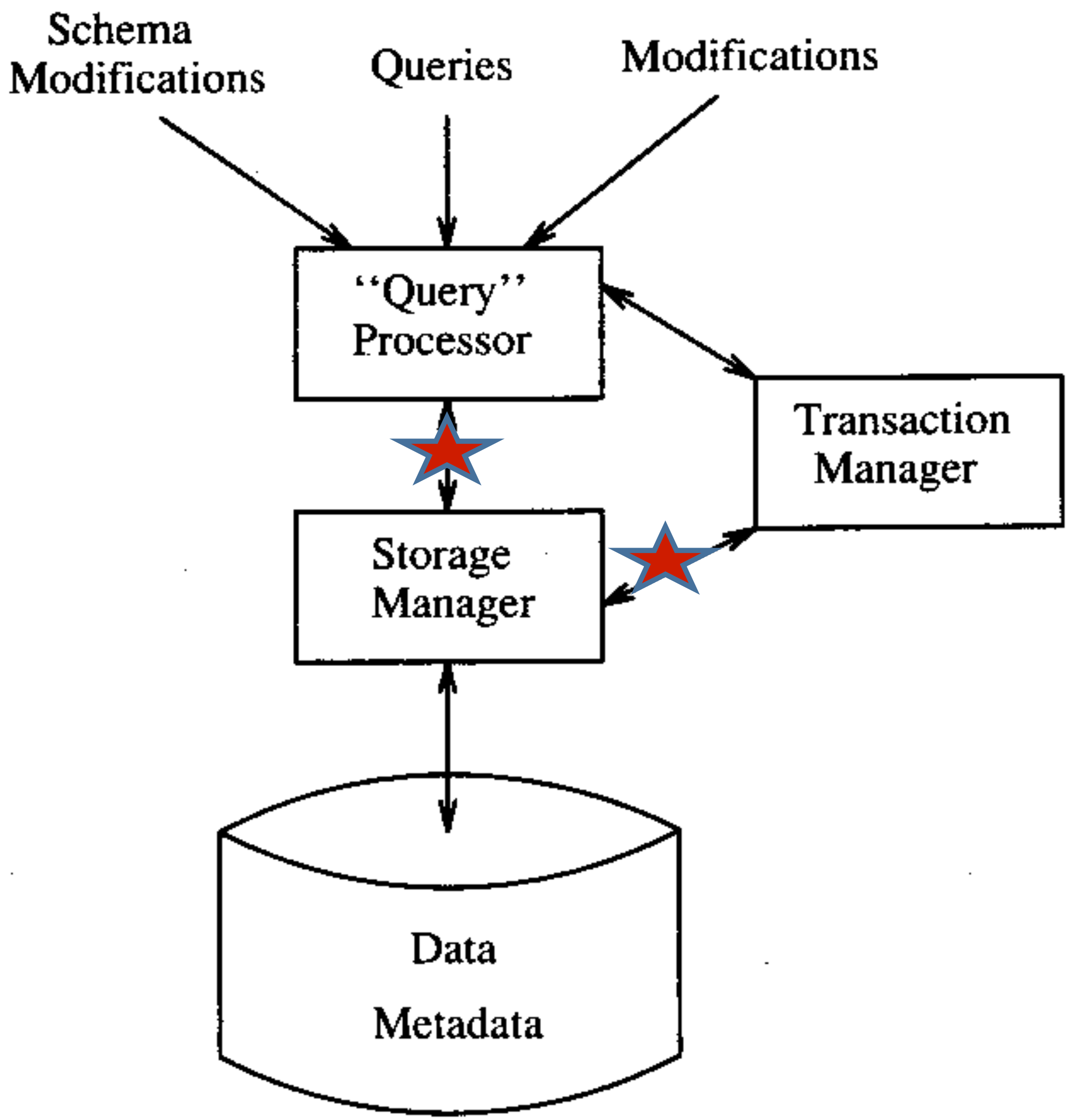
Example Scenario

- RDBMS = "Relational" DBMS
- The relational model uses relations or tables to structure data
- ClassList relation:

Student	Course	Grade
Hermione Grainger	Potions	A
Draco Malfoy	Potions	B
Harry Potter	Potions	A
Ron Weasley	Potions	C

- Relation separates the logical view (externals) from the physical view (internals)
- Simple query languages (SQL) for accessing/modifying data
  – Find all students whose grades are better than B.
  – SELECT Student FROM ClassList WHERE Grade >"B"

DBMS Architecture



Transaction Processing

- One or more database operations are grouped into a "transaction"
- Transactions should meet the "ACID test"
  - **A**tomicity: All-or-nothing execution of transactions.
  - **C**onsistency: Databases have consistency rules (e.g. what data is valid). A transaction should NOT violate the database's consistency. If it does, it needs to be *rolled back.*
  - **I**solation: Each transaction must appear to be executed as if no other transaction is executing at the same time.
  - **D**urability: Any change a transaction makes to the database should persist and not be lost.

Disadvantages over (flat) files?

Disadvantages over (flat) files

- Price
- additional expertise (SQL/DBA)

(hence: over-kill for small, single-user data sets

But: mobile phones (eg., android) use sqlite)

A Brief History of DBMS

- The earliest databases (1960s) evolved from file systems
  - File systems
    - Allow storage of large amounts of data over a long period of time
    - File systems do not support:
      - Efficient access of data items whose location in a particular file is not known
      - Logical structure of data is limited to creation of directory structures
      - Concurrent access: Multiple users modifying a single file generate non-uniform results
    - Navigational and hierarchical
    - User programmed the queries by walking from node to node in the DBMS.

- Relational DBMS (1970s to now)
  - View database in terms of relations or tables
  - High-level query and definition languages such as SQL
  - Allow user to specify what (s)he wants, not how to get what (s)he wants

- Object-oriented DBMS (1980s)
  - Inspired by object-oriented languages
  - Object-relational DBMS

The DBMS Industry

- A DBMS is a software system.
- Major DBMS vendors: Oracle, Microsoft, IBM, Sybase
- Free/Open-source DBMS: MySQL, PostgreSQL, Firebird.
  - Used by companies such as Google, Yahoo, Lycos, BASF….
- All are "relational" (or "object-relational") DBMS.
- A **multi-billion dollar** industry

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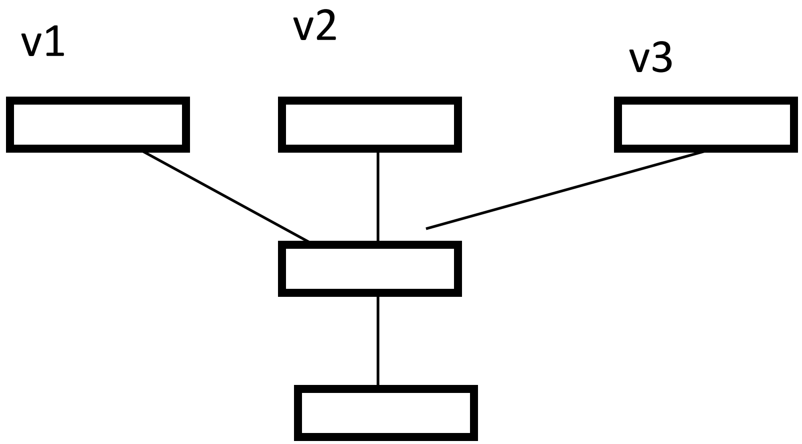
Fundamental concepts

- 3-level architecture
- logical data independence
- physical data independence

3-level architecture

- view level
- logical level
- physical level



3-level architecture

- view level
- logical level: eg., tables
  - STUDENT(ssn, name)
  - TAKES (ssn, cid, grade)
- physical level:
  - how are these tables stored, how many bytes / attribute etc

3-level architecture

- view level, eg:
  - v1: select ssn from student
  - v2: select ssn, c-id from takes
- logical level
- physical level

3-level architecture

- -> hence, **physical** and **logical** data independence:
- logical D.I.:
  - ???
- physical D.I.:
  - ???

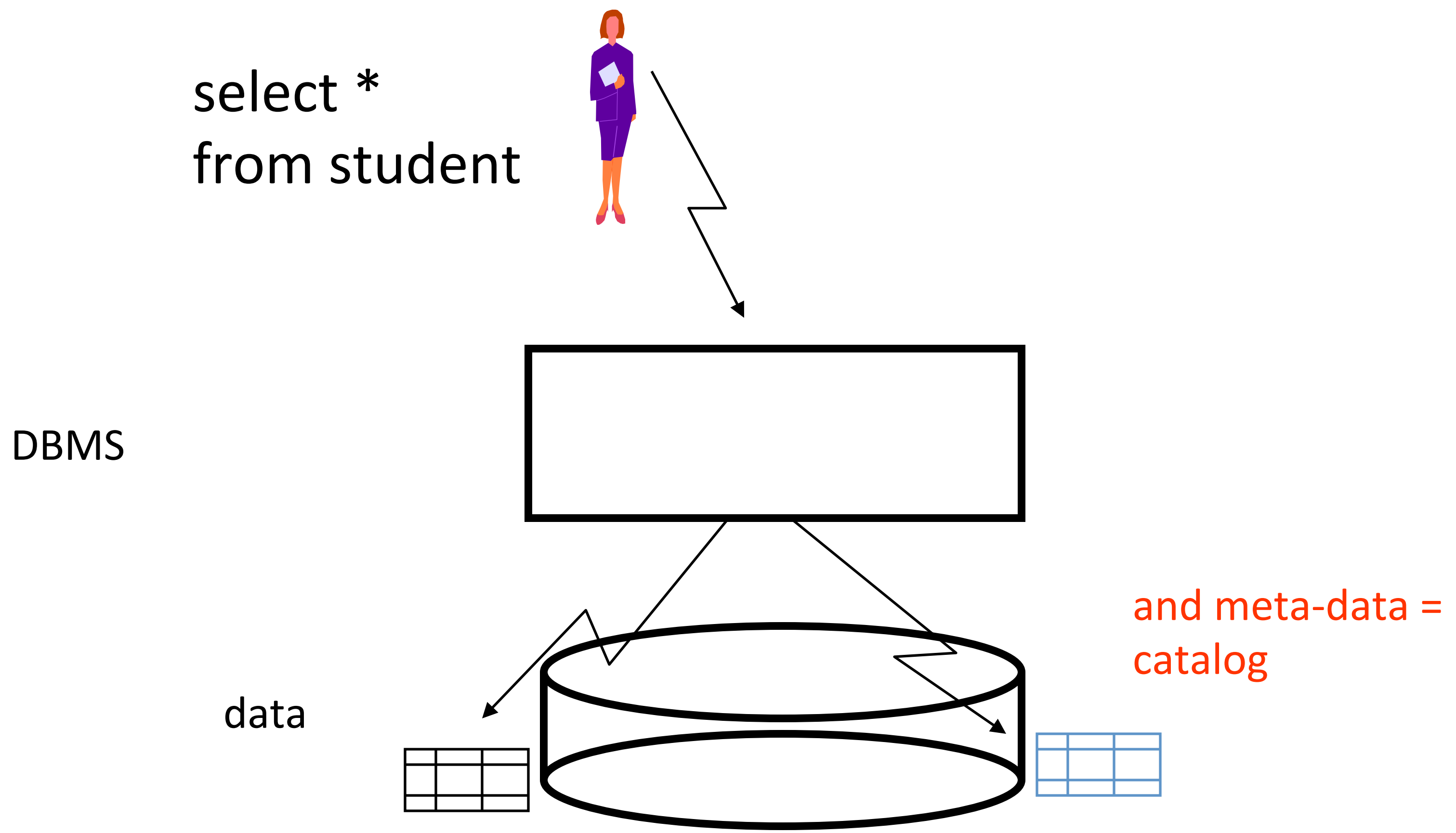
3-level architecture

- -> hence, **physical** and **logical** data independence:
- logical D.I.:
  - – can add (drop) column; add/drop table
- physical D.I.:
  - – can add index; change record order

Database users

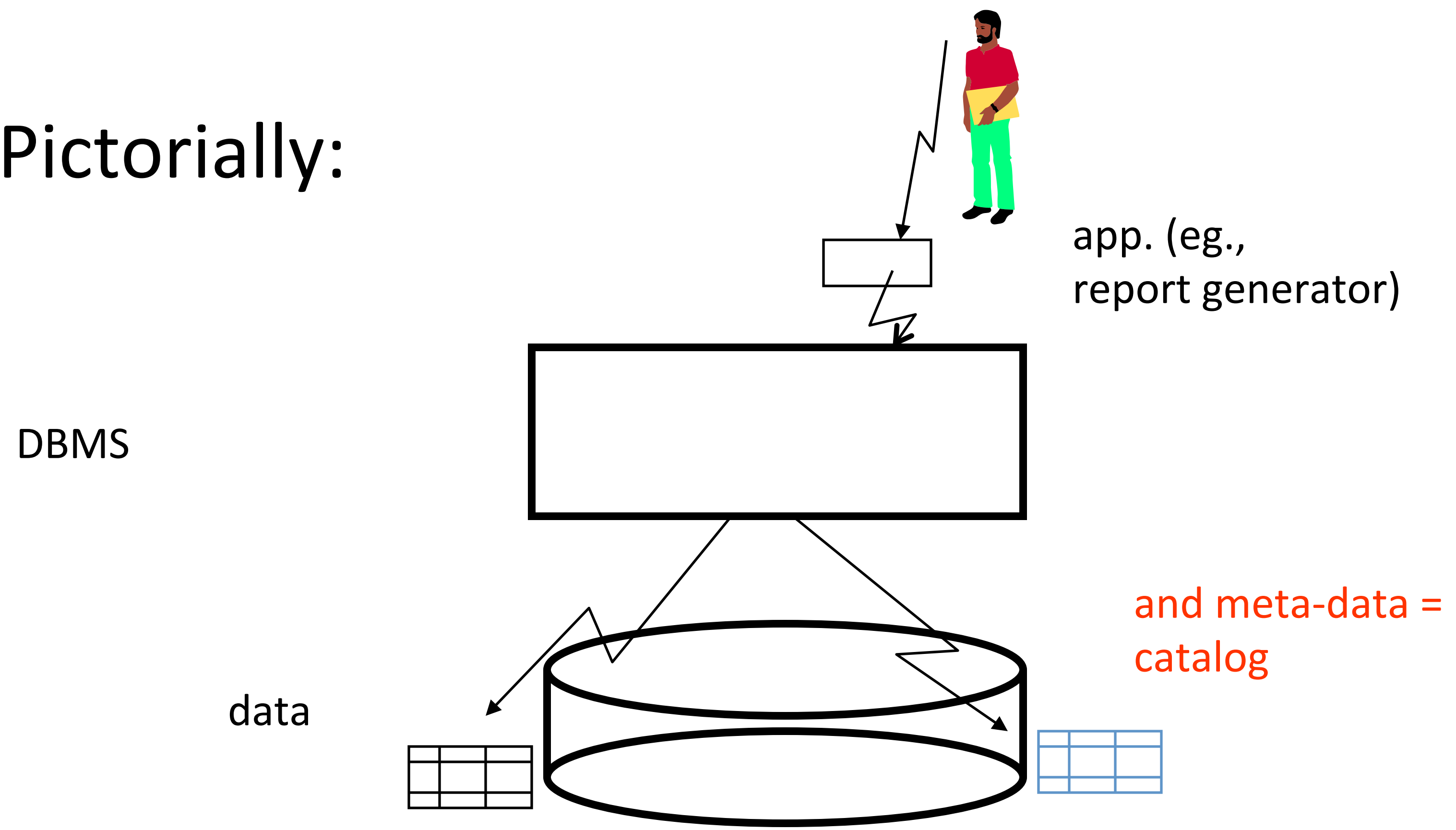
- ‘naive’ users
- casual users
- application programmers
- [DBA (Data base administrator)]

Casual users



``Naive'' users

Pictorially:



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App. programmers

- those who write the applications (like the ‘report generator’)

DB Administrator (DBA)

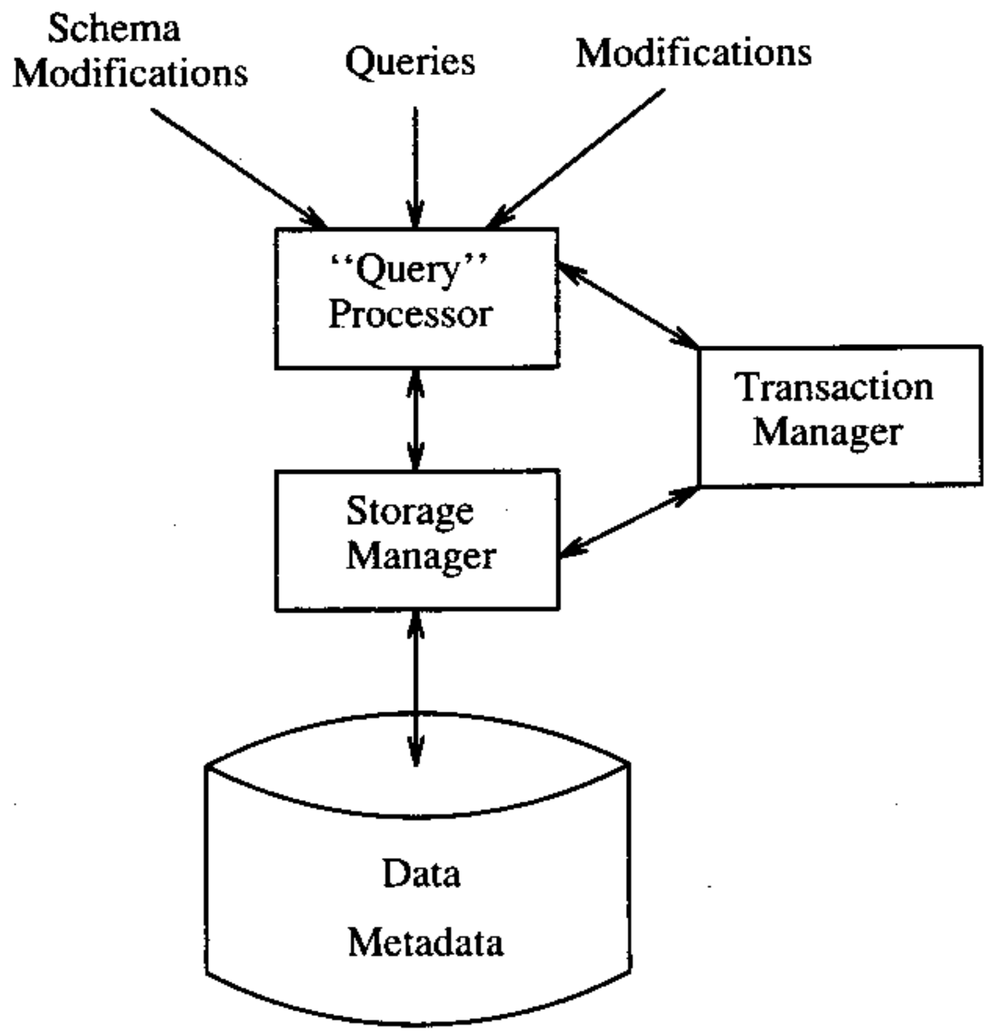
- Duties?

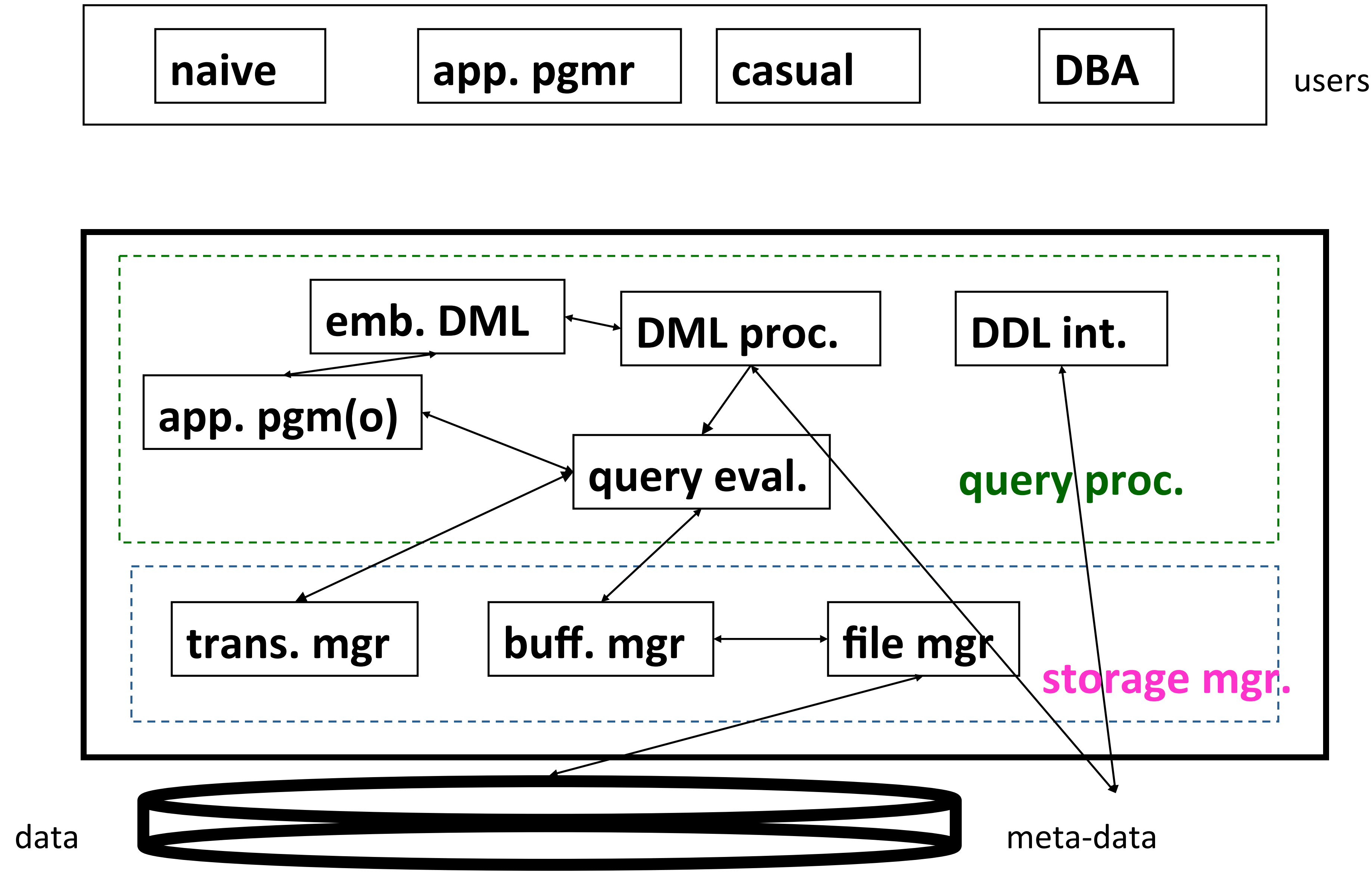
DB Administrator (DBA)

- schema definition ('logical' level)
- physical schema (storage structure, access methods
- schemas modifications
- granting authorizations
- integrity constraint specification

Overall system architecture

- [Users]
- DBMS
  - query processor
  - storage manager
  - transaction manager
- [Files]

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DBA
users
emb. DML
DML proc.
DDL int.
app. pgm(o)
query eval.
query proc.
trans. mgr
buff. mgr
file mgr
storage mgr.
data
meta-data

Overall system architecture

- query processor
  - DML compiler
  - embedded DML pre-compiler
  - DDL interpreter
  - Query evaluation engine

Overall system architecture (cont'd)

- storage manager
  - authorization and integrity manager
  - transaction manager
  - buffer manager
  - file manager

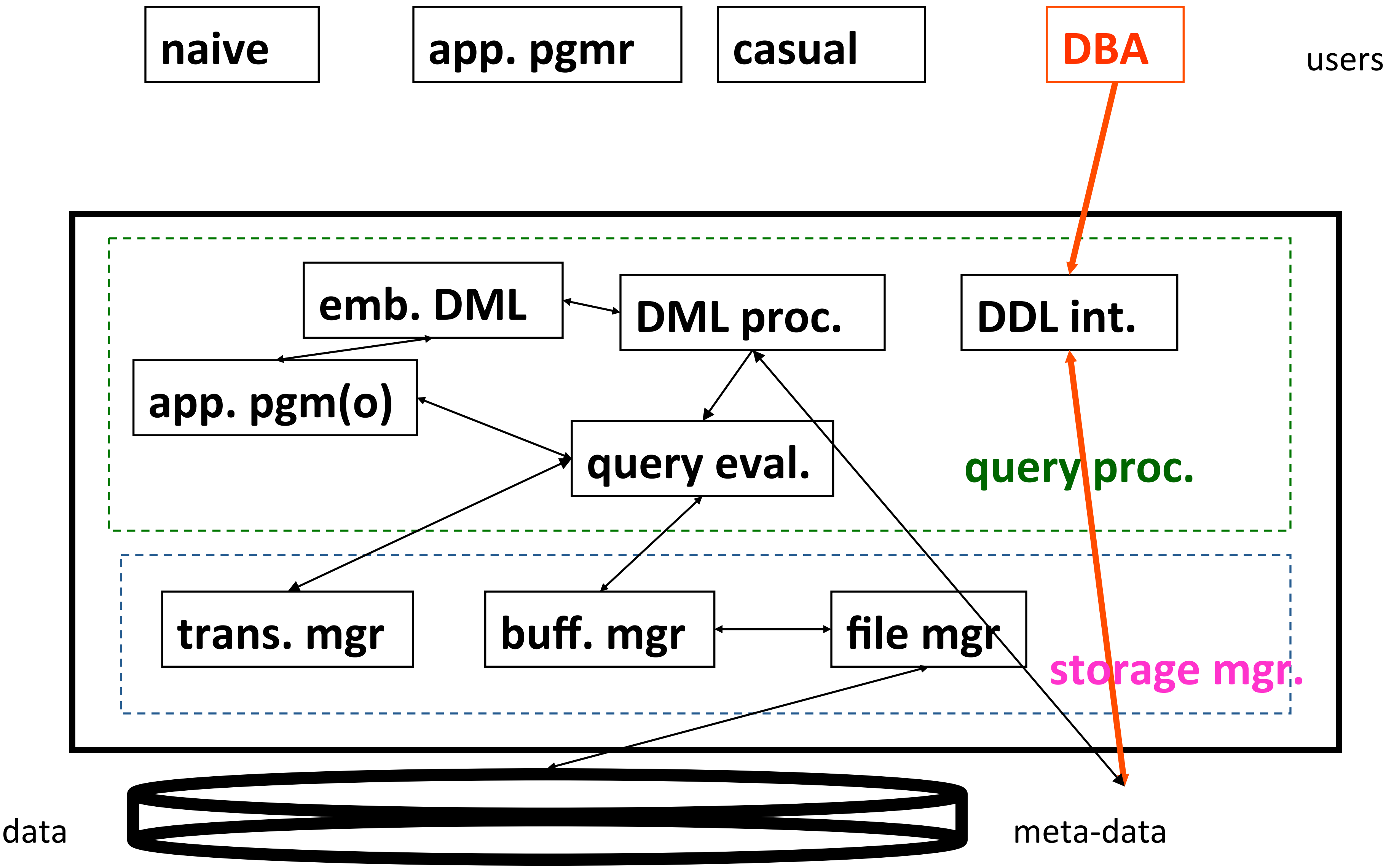
Overall system architecture (cont'd)

- Files
  - data files
  - data dictionary = catalog (= meta-data)
  - indices
  - statistical data

Some examples:

- DBA doing a DDL (data definition language) operation, eg.,

  create table student ...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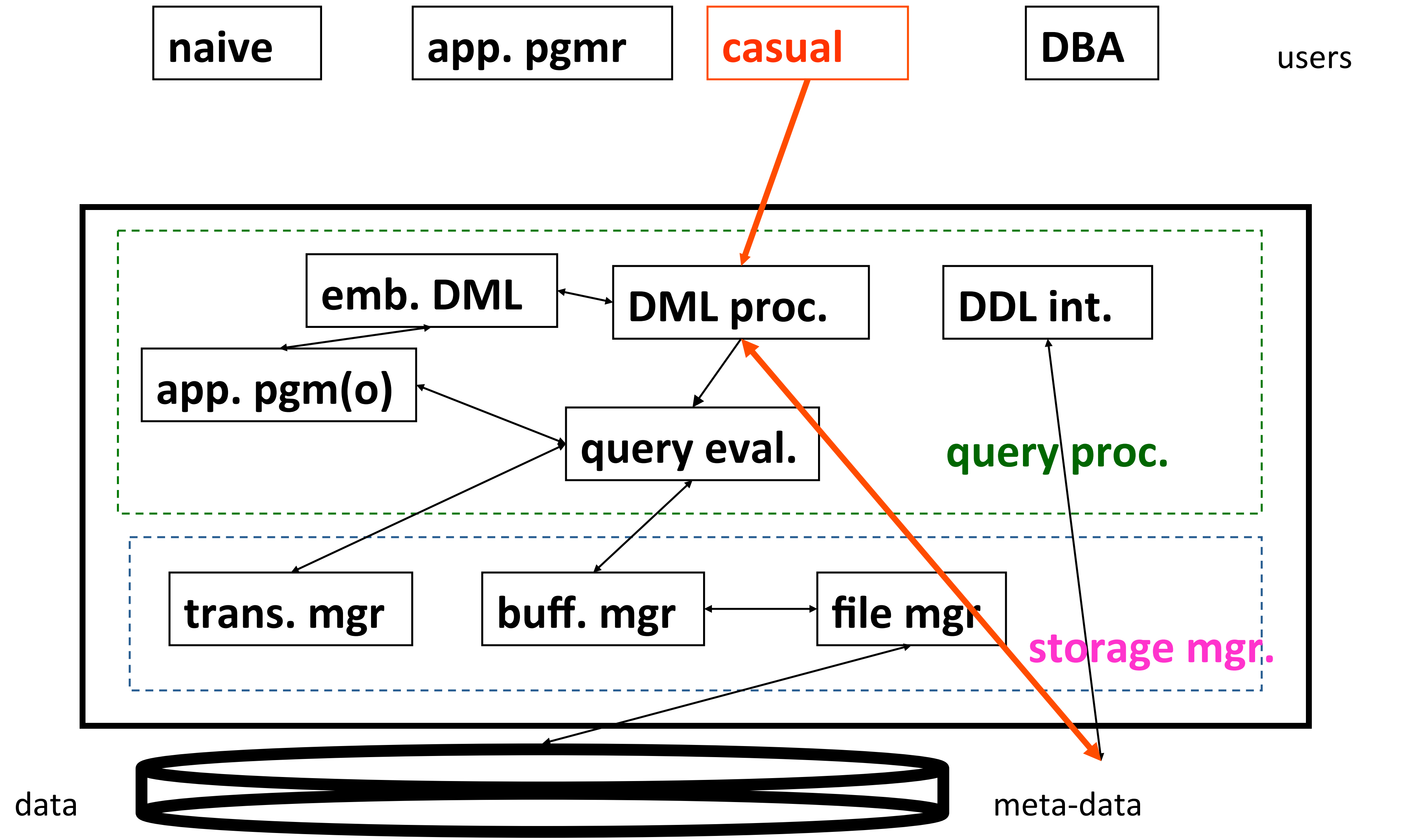
Some examples:

- casual user, asking for an update, eg.:

  update student

  set name to 'smith'

  where ssn = '345'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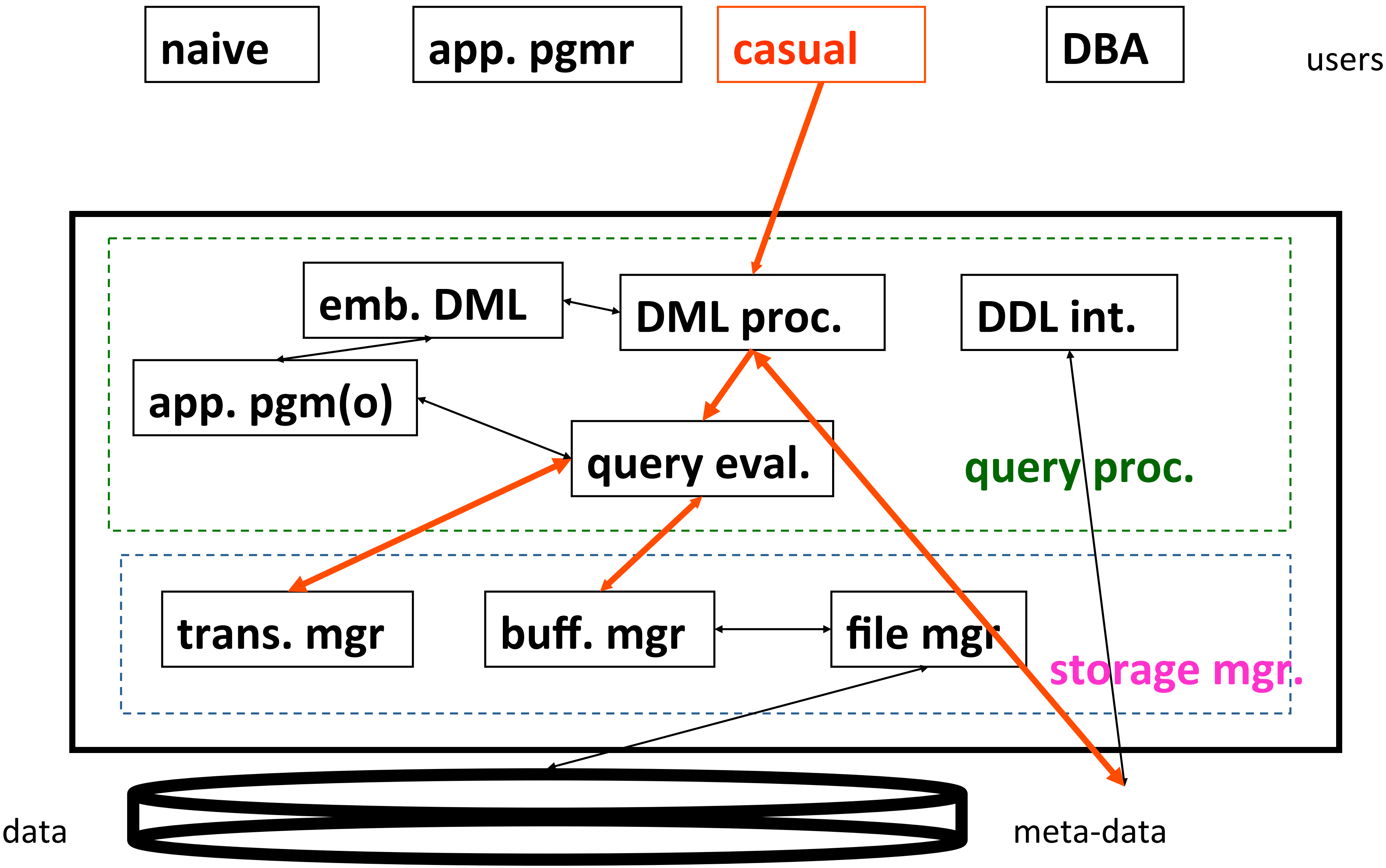
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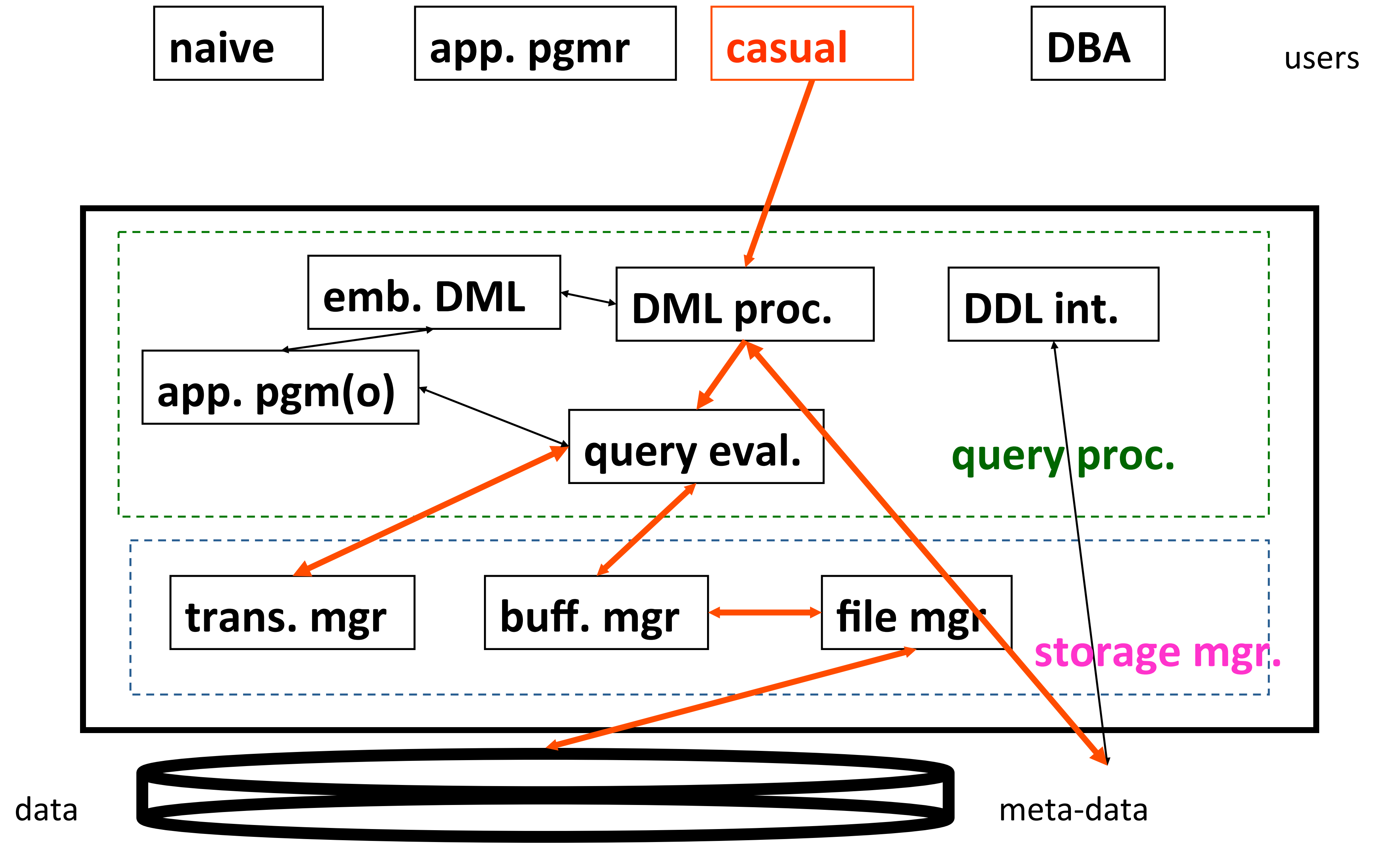
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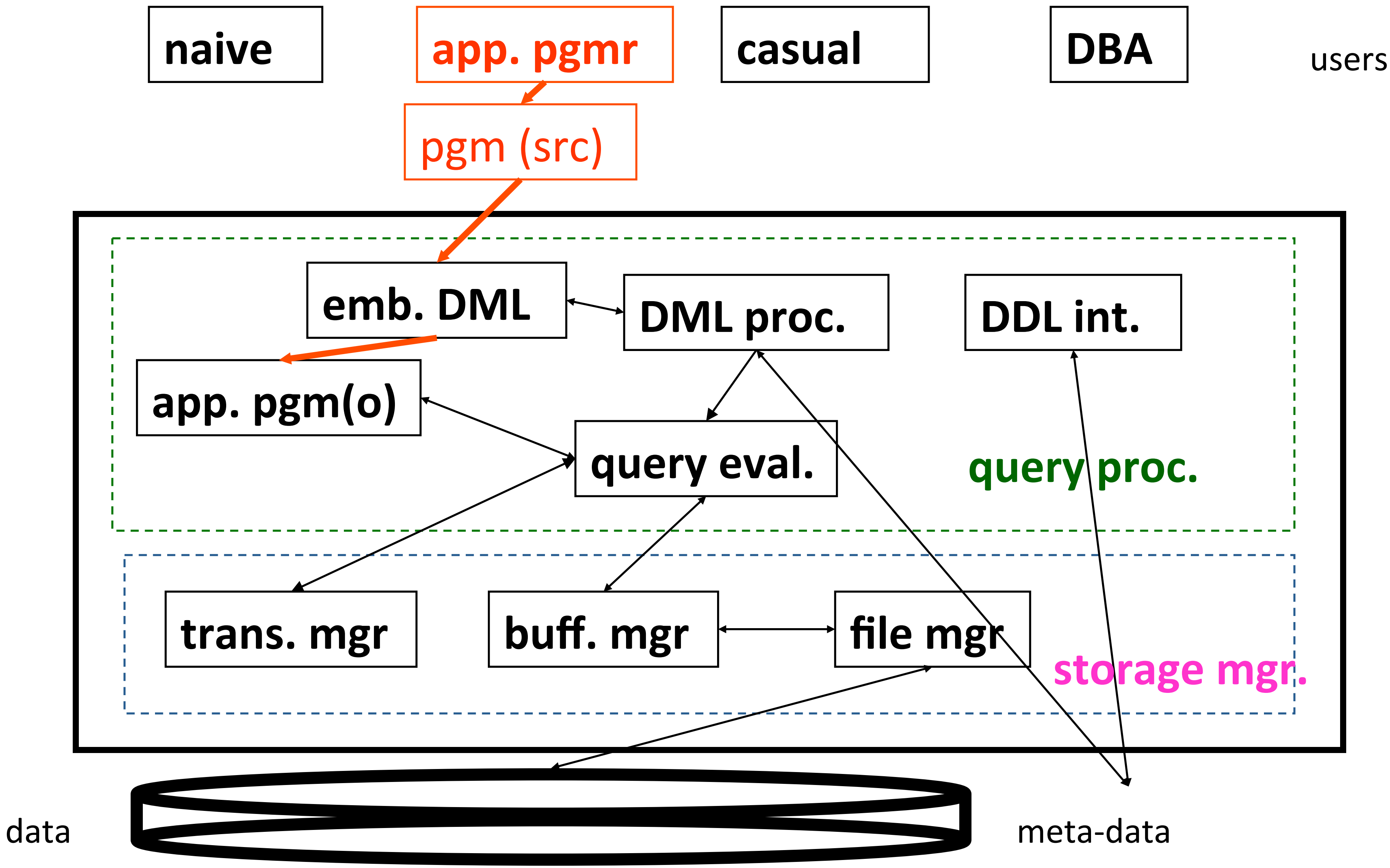
Some examples:

- app. programmer, creating a report, eg

```
main(){
....
exec sql "select * from student"
...
}
```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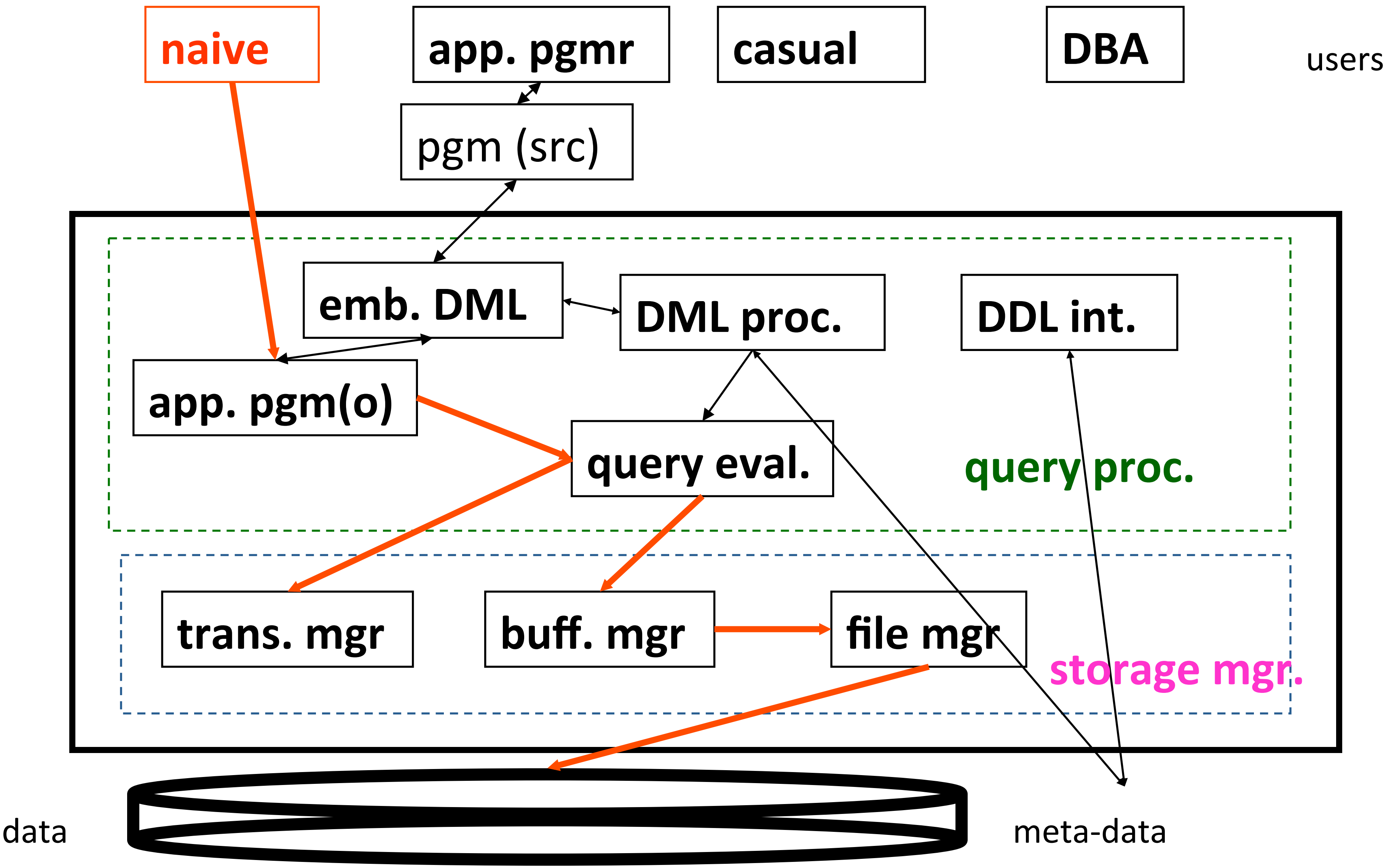
Some examples:

- ‘naive’ user, running the previous app.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Conclusions

- (relational) DBMSs: electronic record keepers
- customize them with **create table** commands
- ask SQL queries to retrieve info

Conclusions contd

main advantages over (flat) files & scripts:

- **logical + physical data independence** (ie., flexibility of adding new attributes, new tables and indices)
- **concurrency control** and **recovery**